UTAH DEPARTMENT *of* ENVIRONMENTAL QUALITY
WATER QUALITY

PROPOSED NUTRIENT CRITERIA: UTAH HEADWATER STREAMS

Application of Stressor-Response Models and Multiple Lines of Evidence

June 2019

Prepared by the Utah Division of Water Quality

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ABBREVIATIONS AND ACRONYMS

Abbreviations and acronyms used in this proposal, separated into those associated with nutrients, then all others.

Nutrients	
N	Nitrogen, expressed as mg/L unless otherwise noted.
P	Phosphorus, expressed as mg/L unless otherwise noted.
TIN	Dissolved inorganic nitrogen, expressed as mg/L unless otherwise noted.
TN	Total nitrogen, expressed as mg/L unless otherwise noted.
TP	Total phosphorus, expressed as mg/L unless otherwise noted.
Others (in Alphabetic Order)	
AFDM	Ash free dry mass: a measure of the amount of organic material in a sample. For this report it is an alternative measure to chlorophyll-*a* used to quantify benthic algae density. Expressed as grams of carbon/m^2.
BMP	Best management practice
Chl-*a*	Chlorophyll-a: a measure of the amount of chlorophyll in a sample. In this case, it is used as a quantitative estimate of the amount of living algal material in a sample. Expressed as grams of chl-*a*/m^2.
DO	Dissolved oxygen: typically expressed as mg/L
DWQ	Utah Division of Water Quality
ER	Ecosystem respiration: the heterotrophic component of whole stream metabolism measures (see Table 2); in this report expressed as g O_2/m^2/day consumed by stream organisms.
GPP	Gross primary production: the autotrophic component of whole stream metabolism measures (see Table 2); in this report expressed as g O_2/m^2/day produced by plants and algae within the stream.
MOU	Memoranda of Understanding
NNC	Numeric nutrient criteria: in this case this includes N and P concentration in addition to coupled responses.
POTW	Publicly owned treatment works
predTN	Predicted total nitrogen
SAP	Sample and analysis plan: in this case detailed plans that describe the monitoring and assessment methods that will be followed for purposes of developing site-specific numeric criteria.

S-R	Stressor-response: empirical models that relate stressors—in this case nutrients, to various ecological responses.
SRP	Soluble reactive phosphorus
TMDL	Total maximum daily load: studies conducted under the Clean Water Act that determine pollutant reductions that are necessary to meet water quality standards.
UAC	Utah Administrative Code
USEPA	United States Environmental Protection Agency

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Craig Walker, Division of Wildlife Resources
Jim Webb, Circle 4 Farms (Agricultural Producers)

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Utah Nutrient Strategy

PROPOSED NUMERIC NUTRIENT CRITERIA FOR UTAH'S HEADWATER STREAMS

EXECUTIVE SUMMARY

Utah's Division of Water Quality (DWQ) proposes tiered numeric nutrient criteria (NNC) to protect aquatic life uses in headwater streams where streams are placed into one of three enrichment tiers depending on whether or not ambient nutrient concentrations exceed two nutrient concentration thresholds (Table 1). Under this proposal, the lower criteria of 0.4 mg/L for total nitrogen (TN) and 0.035 mg/L for total phosphorus (TP) differentiate between low and moderate enrichment streams. A higher threshold of 0.80 mg/L for TN and 0.080 mg/L for TP differentiates between moderate and high enrichment streams. Moderate enrichment streams, with nutrient concentrations between the upper and lower thresholds, require measures of ecological condition to determine whether or not enrichment is impairing or threatening a stream's designated uses.

Nutrients can degrade aquatic life uses via mechanisms related to increased growth of plants/algae (autotrophs) and/or microbes/fungi (heterotrophs). DWQ selected bioconfirmation criteria (ecological responses) to address both mechanisms. In the case of plant/algae growth, two ecological responses are not-to-be-exceeded at any headwater stream: (1) a daily gross primary production (GPP) rate higher than 6 g O_2/m^2/day or (2) an aerial percent filamentous algae cover exceeding 1/3 of the stream bed. Linkages among microbes/fungi, nutrients, and aquatic life uses are less well understood, in part because these processes are more difficult to observe or measure. However, it is possible to measure ecosystem respiration (ER), which captures the net metabolic activities of all stream biota. DWQ proposes a not-to-be-exceeded rate for ER of 5 g O_2/m^2/day.

Nutrients can also degrade recreation uses. To protect these uses DWQ proposes a not-to-be-exceeded benthic algae concentration of 125 mg/chlorophyll-*a* (chl-*a*)/m^2, or the equivalent 49 g ash free dry mass (AFDM)/m^2. These criteria are supported by the responses from a survey of Utah citizens who were asked whether streams with varying amounts of benthic algae cover represented "desirable" or "undesirable" conditions. These criteria fall just below the point where the proportion of undesirable responses start to increase and should therefore be protective of recreation from the perspective of degraded aesthetics or other factors influencing recreational use decisions.

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Table 1. Numeric Nutrient Criteria and Associated Ecological Responses (Bioconfirmation Criteria) Proposed to Protect Aquatic Life Uses in Antidegradation Category 1 and 2 (UAC R317-2-12)[f] Headwater Perennial Streams

Low Nutrient Enrichment at Headwater Streams: No Ecological Responses			
Summertime Average Nutrients			**Assessment Notes**
TN < 0.40[a,b]	TP < 0.035[a,b]		Fully supporting aquatic life uses if the average of ≥ 4 summertime samples for both TN and TP fall below the specified nutrient concentrations. However, it is not supporting aquatic life uses, cause unknown, if the ecological responses specified for moderate enrichment streams are exceeded. Sites with fewer samples will not be assessed for nutrients.
Moderate Nutrient Enrichment at Headwater Streams and Ecological Responses			
Summertime Average Nutrients		**Ecological Response**	**Assessment Notes**
TN 0.40–0.80[a]	TP 0.035–0.080[a]	Plant/Algal Growth[c] < 1/3 or more filamentous algae cover[d,e] OR GPP[c] of < 6 g O_2/m^2/day OR ER[c] < 5 g O_2/m^2/day	Headwater streams within this range of nutrient concentrations will be considered impaired (not supporting aquatic life uses) if <u>any</u> response exceeds defined thresholds. Streams <u>without response data</u> will be listed as having <u>insufficient data</u> and prioritized for additional monitoring if either TN or TP falls within the specified range.
High Nutrient Enrichment at Headwater Streams: No Ecological Responses[e]			
Summertime Average Nutrients			**Assessment Notes**
TN > 0.80[a,b]	TP > 0.080[a,b]		Streams over these thresholds will initially be placed on Utah's Section 303(d) list as threatened. Threatened streams will be further evaluated using additional data such as nutrient responses, biological assessments, or nutrient-related water quality criteria (e.g., pH and DO) both locally and in downstream waters.

Notes: Criteria are applicable during the period of algae growth through senescence unless more restrictive total maximum daily load (TMDL) targets have been established to ensure the attainment and maintenance of downstream waters. DO = dissolved oxygen, ER = ecosystem respiration, GPP = gross primary production, TN = total nitrogen in mg/L, and TP = total phosphorus in mg/L.
a. Seasonal average of ≥ 4 samples collected during the period of algae growth through senescence will not be exceeded. Sites will be assessed using the higher of TN and TP threshold classifications.
b. Response data, when available, will be used to assess aquatic life use support or as evidence for additional site-specific investigations to confirm impairment or derive and promulgate a site-specific exception to these criteria.
c. Daily whole stream metabolism obtained using open-channel methods. Daily values are not to be exceeded on any collection event.
d. Filamentous algae cover means patches of filamentous algae > 1 cm in length or mats > 1 mm thick. Not to be exceeded daily stream average, based on at least 3 transects perpendicular to stream flow and spatially dispersed along a reach of at least 50 meters.
e. Quantitative estimates are based on reach-scale averages with at least three measures from different habitat units (i.e., riffle, run) made with quantitative visual estimation methods.
f. Excluded waters identified in UAC R317-2-14, Footnotes for Table 2.14.7 and Table 2.14.8.

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This proposal provides the background and rationale for the proposed NNC and describes the proposed approach to implementing the NNC for assessments. The introductory section describes why nutrients are a water quality concern and why DWQ decided to prioritize headwater streams for the development of NNC.

The "Development of Numeric Nutrient Criteria" section summarizes the investigations that underpin the NNC and how the thresholds for TP, TN, and ecological responses were calculated. A companion document, *Technical Support Document: Utah's Nutrient Strategy* (Ostermiller et al. 2018) provides much more detail on the investigations and calculations and includes a thorough review of related scientific literature.

The "Rationale behind Proposed Headwater Numeric Nutrient Criteria" section presents the rationale behind the magnitude, duration, and frequency of DWQ's proposed NNC. This section provides context for DWQ's proposed NNC by benchmarking them against criteria proposed by others and comparing them to thresholds presented in the scientific literature. The proposed rule language is provided in the document appendix.

The final section, "Programmatic Implications", provides regulatory context. It briefly explains how the NNC would interface with other DWQ programs and how they would be implemented as part of DWQ's monitoring and assessment programs. The section also sets out a process for modifying the proposed criteria, if needed, on a site-specific basis. It also presents DWQ's proposal for ongoing collaborative management for implementation of the criteria.

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INTRODUCTION

Why are excess nutrients a concern?

Nutrients provide critical support for both stream and lake food webs. However, excess accumulation of nutrients, particularly nitrogen (N) and phosphorous (P), causes numerous water quality problems that have been demonstrated to degrade aquatic life, drinking water, and recreation uses. Resulting economic losses from these degraded conditions are considerable—in the United States estimated costs from N exceed $210 billion annually or $254/ha/yr. (Sobata et al. 2015). More importantly, these problems threaten the sustainability of Utah's water resources and diminish the quality of life for Utahns (CH2MHill 2012). Problems associated with excess nutrients in waterbodies from human activities (collectively called cultural eutrophication) have been documented for almost two centuries (Smith et al. 1999, Bricker at al. 2008). However, cultural eutrophication problems in the United States have been rapidly increasing in extent and magnitude over the past 50 years due to the combination of widely available commercial fertilizers and exponential population growth. Many water resource professionals and regulatory agencies—including the United States Environmental Protection Agency (USEPA) and Utah's Division of Water Quality (DWQ)—now consider cultural eutrophication to be among the greatest threats to lakes, rivers, and estuaries in Utah (USEPA 2009).

> Nutrient pollution is among the most widespread and challenging of water quality problems. Nutrient pollution can degrade aquatic life, drinking water, and recreational uses through a variety of complex mechanisms.

Excess nutrients can degrade surface water quality in various ways. Many of these processes are associated, directly or indirectly, with excess plant and algae growth and/or rates of microbial decomposition of organic matter. For most people, problems associated with plant and algae growth are the most obvious because such growth is unsightly and degrades the aesthetics of lakes and streams (Suplee et al. 2009, CH2MHill 2012). Less obvious are very low levels of dissolved oxygen (DO) that occur when plants and algae consume oxygen at night and decompose when they die. Sometimes, low DO problems are severe enough to cause extensive fish kills (Dodds 2007, Smale and Rabeni 1985).

Another less obvious consequence of cultural eutrophication is the loss of biodiversity in lakes and streams (Jeppasen et al. 2000). Losses of resident species typically start with changes in water chemistry (e.g., low DO) and habitat degradation (e.g., increased sedimentation, reduced water clarity) and result in a competitive advantage for species adapted to high nutrient conditions at the expense of more sensitive species (Davies and Jackson 2006). Such losses are important because they diminish the ecological resilience of waterbodies, making it more difficult for them to recover from extreme events such as droughts and floods (Folke et al. 2004). Recent evidence also suggests that reductions in algal biodiversity causes negative feedback that reduces nutrient uptake rates, which has the potential to further degrade water quality at downstream waterbodies (Cardinale 2011).

In lakes, excessive primary production sometimes manifests as growth of cyanobacteria (or blue-green algae), which can produce toxins that are harmful to people and animals (Hudnell 2000). These toxins directly threaten the security of culinary water supplies because they cannot be easily removed with standard treatment processes. Sometimes the toxicity of “blooms” can even be deadly, particularly for animals like dogs and cattle (Briand et al. 2003).

Groundwater culinary sources are also threatened by excess nutrients because they can become contaminated with nitrate, a form of N that can be toxic, especially to infants (Dubrovsky and Hamilton 2010). In addition, nitrate and P in groundwater can migrate to streams and lakes, with the potential to contribute to negative nutrient-related responses downstream (Holman et al. 2008, Paerl 1997). Enrichment of groundwater sometimes takes years to manifest; once contamination occurs, remediation is often exceedingly difficult. In Utah, groundwater nitrate contamination has caused several municipal and private drinking water sources to exceed federal human health criteria.

All these harmful responses to excess nutrients have been observed in Utah, and DWQ is committed to solving nutrient-related water quality problems. To accomplish this goal, DWQ and stakeholders have been developing a comprehensive nutrient reduction strategy. The strategy consists of identifying waterbodies with nutrient-related problems and implementing appropriate nutrient reductions with programs directed at various nutrient sources. Nutrient-related water quality issues are currently addressed through the development of total maximum daily load (TMDL) documents and watershed-scale planning. Adoption of numeric nutrient criteria (NNC) for headwaters provides additional tools DWQ can use when managing the most pristine and protected waters in Utah and when assessing ways to maintain or improve their quality.

Why headwater streams?

Headwater streams are critically important ecosystems—both ecologically and economically. Ecologically, headwater streams contribute to the biological integrity of all streams by providing critical hydrologic connectivity among streams across large landscapes (Freeman et al. 2007). At regional scales headwater streams are critically important for the maintenance of aquatic biodiversity (“β-diversity”; Clarke at al. 2008), in part because they are physically diverse with a corresponding rich diversity of potential habitats (Lowe and Likens 2005). Native fish, like Utah’s cutthroat trout (*Oncorhynchus clarkii*), inhabit these streams year-round or migrate to them in early spring to spawn (Schrank and Rahek 2004). In an economic context, headwater streams provide many important ecosystem services. These streams protect downstream waters through nutrient retention (Bernhardt et al. 2005), maintenance of sediment transport (Lowe and Likens 2005), and organic matter storage and processing. Moreover, protecting headwaters from cultural eutrophication will have the added benefit of protecting downstream waters because a large percentage of nutrients that enter these waters are ultimately transported downstream (Newbold et al. 1981).

In Utah, the majority of water falls as mountain snow, so these catchments are a critical part of the state's water future. For over three decades, DWQ has acknowledged the importance of headwater streams and afforded them Antidegradation Category 1 or 2 protections (Utah Administrative Code [UAC] R-317-2). These are among the most pristine waters in the state; generally, no permitted discharges are permitted in Category 1 waters, and discharges only at background concentrations are permitted in Category 2 waters. All told, Utah has approximately 8,000 miles of perennial headwater streams (as defined here), which is about 47% of the total perennial stream miles in Utah.

> "It is difficult to see how any conservation action with the goal of protecting the long-term ecological integrity and ecosystem services of natural systems, whether aquatic or terrestrial, can succeed without a foundation of intact and functional headwaters." Lowe and Likens 2005

DWQ also has practical reasons for starting NNC development with headwater streams. It is easier to estimate undegraded conditions, with respect to both nutrient concentrations and ecological responses, for headwater streams than for streams lower in the watershed that often are affected by multiple stressors. Determining appropriately protective water quality goals in headwaters is more straightforward because reference quality streams are more numerous and can be used to obtain more accurate estimates of undegraded conditions. Water quality goals that are defined by reference conditions are generally appropriate in headwaters because they are achievable, whereas some conditions in downstream reaches are irreversible due to permanent changes in hydrology or habitat.

While regional NNC are appropriate for headwaters, DWQ has determined that site-specific approaches are likely more appropriate in downstream waters due to several factors. The first relates to the influence of covariates. Stream ecologists have known for decades that many ecological attributes change naturally and predictably from headwaters to downstream reaches (i.e., see Vanote et al. 1980). Water quality goals, particularly for naturally occurring pollutants like N and P, need to be adjusted to account for these natural changes. Another complication in developing defensible water quality goals for downstream waters relates to patterns of human land use. Most of Utah's population resides in valleys. As a result, both the number of stressors on steam ecosystems and the magnitude of their influence on stream organisms increase from headwaters to downstream reaches. Many of these stressors cause patterns of degradation that are similar to nutrients, which makes it difficult to separate the effects of many different causes of ecological degradation (Allan 2004). Together, these factors make the development of NNC for headwaters a logical first step in Utah's overall nutrient strategy.

What are numeric nutrient criteria?

NNC define the magnitude (maximum concentration), duration (averaging periods), and frequency (acceptable number of violations) of N or P concentrations that must be maintained to prevent the degradation of existing beneficial uses. In addition, NNC can also include ecological responses as water quality goals based on potentially deleterious responses to nutrients. NNC, such as those proposed here, that include both nutrient concentrations and ecological responses are sometimes called "combined criteria." Regional NNC, such as those that DWQ proposes for headwaters, are typically derived from thresholds obtained from two methods: empirical stressor-response (S-R) relationships and regional distributions of N and P concentrations (USEPA 2000). DWQ used both approaches as lines of evidence to establish NNC that are appropriately protective of aquatic life and recreational uses in headwater perennial streams. A third approach for development of NNC, mechanistic modeling, are anticipated to be applicable for developing site-specific NNC in the future (primarily for downstream waters).

> Numeric nutrient criteria establish concentrations of nitrogen and phosphorus and sometimes ecological responses that should not be exceeded to avoid the impairment of the designated uses—typically aquatic life or recreation—of lakes or streams.

Why are numeric nutrient criteria important?

While many states, including Utah, conduct water quality assessments based on indicators that can be used to infer nutrient-related ecological responses (e.g., DO, pH), USEPA has determined that these approaches are not resulting in nutrient reduction programs that adequately protect beneficial uses from the degradation of designated uses that sometimes results from nutrient pollution. Instead, USEPA has determined that comprehensive nutrient reduction programs must be developed to protect aquatic ecosystems (USEPA 2011a). USEPA's policy directs each state to develop a nutrient reduction program; a key component of such programs is developing NNC so it is clear when protective action is needed.

The most important consideration from the perspective of DWQ is that NNC are appropriately protective—they should accurately identify streams with nutrient-related problems without diverting resources where nutrient-related problems are not manifest.

Nutrient pollutants are among the most important threats to water quality and have not yet been explicitly addressed in Utah's water quality standards.

What streams are captured by these criteria?

DWQ proposes to generally apply these NNC to perennial headwater streams that are currently protected as Antidegradation Category 1 and 2 waters (Figure 1). These streams consist of waters that Utah's Water Quality Board has determined are "of exceptional recreational or ecological significance or have been determined to be a State or National resource requiring

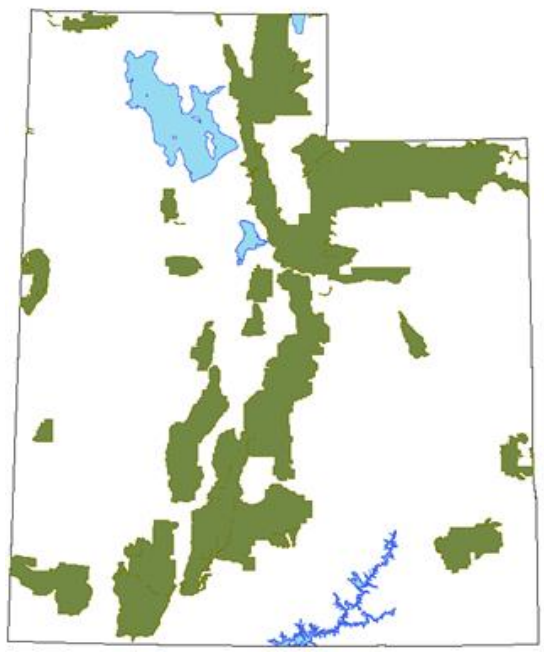

Figure 1. Map of headwater stream watersheds.

protection" (UAC R317-2-12). In Utah these streams include, among others, all stream segments within United States Forest Service (USFS) boundaries, which encompass approximately 8.2 million acres, over 15% of the acreage in Utah (Gorte et al. 2012). The only Category 1 and 2 streams excluded from these criteria are three small sections of stream, totaling approximately nine river miles, that have permitted facilities that were grandfathered an exclusion to the prohibition of discharges in current water quality regualtions.

What about streams lower in the watershed?

DWQ is addressing nutrient issues in waters lower in the watershed through the technology based phosphorus effluent limit rule, development and implementation of TMDLs in nutrient impaired waters, and development of site-specific criteria in Utah Lake.

DEVELOPMENT OF NUMERIC NUTRIENT CRITERIA

An Adaptive Management Framework

Considerable uncertainty and controversy, both scientific and socioeconomic, surrounds the development of NNC and the associated nutrient reduction programs that aim to address nutrient pollution. As a result, DWQ and Utah's Nutrient Core Team—a stakeholder group charged with the development of a nutrient reduction program have incorporated an adaptive management framework into several aspects of Utah's nutrient strategy. The adaptive management process begins with implementing initial actions based on the available but often incomplete information. As actions are implemented, concurrent monitoring is used to compare

> Adaptive management is "…the process by which new information about the health of the watershed is incorporated into the watershed management plan. Adaptive management is a challenging blend of scientific research, monitoring, and practical management that allows for experimentation and provides the opportunity to 'learn by doing.' It is a necessary and useful tool because of the uncertainty about how ecosystems function and how management affects ecosystems" (USEPA 2003).

results to the plan's objectives and identify successes. Finally, the plan is either maintained or modified based on the analysis of the results, and the process is continued until management objectives are realized.

With respect to Utah's approach to these NNC, DWQ intends to apply this adaptive management approach (Figure 2) for ongoing site-specific modifications to NNC endpoints, where appropriate. Although there is considerable evidence that the proposed NNC are applicable and protective of aquatic life uses, any regionally applied criteria may not account for local stream characteristics that strongly alter a specific stream's sensitivity to nutrient enrichment. These NNC are adaptive because they call for modifying these criteria if ongoing data collection efforts suggest that the criteria—both nutrients and ecological responses—are either overprotective or under-protective of aquatic life uses in a stream.

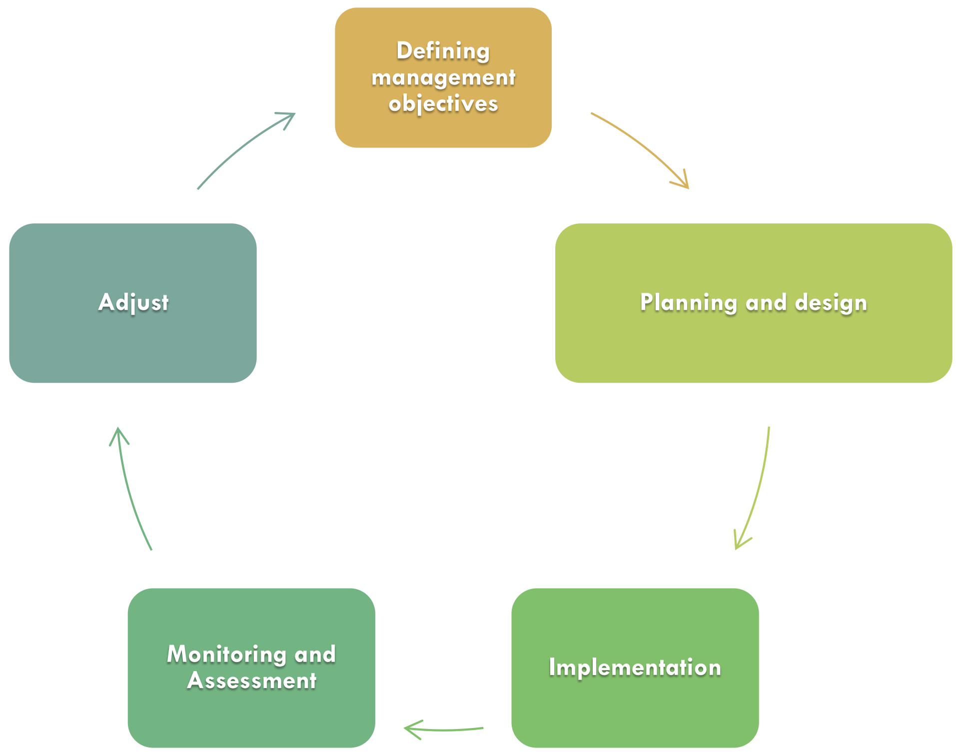

Figure 2. Adaptive management approach for implementing numeric nutrient criteria in Utah's headwater streams.

DWQ also proposes incorporation of adaptive management principles into ongoing implementation of the criteria. DWQ intends to expand its existing collaborative monitoring efforts with other state and federal agencies to include collection of the data needed for NNC assessments. In circumstances where impairments are identified, DWQ will work collaboratively with the U.S. Forest Service and Utah Department of Agriculture and Food to identify the most efficient and equitable solutions possible.

Development of Nutrient-Enrichment Indicators

In addition to specifying TN and total P (TP) concentrations that must be maintained to meet aquatic life uses, DWQ also proposes NNC that combine ecological responses with the lower TN and TP criteria (this combination is sometimes called "combined criteria"). Linkages between nutrient pollution and designated uses are complex, with many interrelated processes (Figure 3). NNC, for both nutrients and responses, require thresholds that can be used to identify degraded conditions. These thresholds are generally defined by evaluating the distribution of reference site TN and TP concentrations and by developing empirical models that relate nutrients to measures of biological condition. For the latter approach, measures of biological condition should be as directly linked to nutrients.

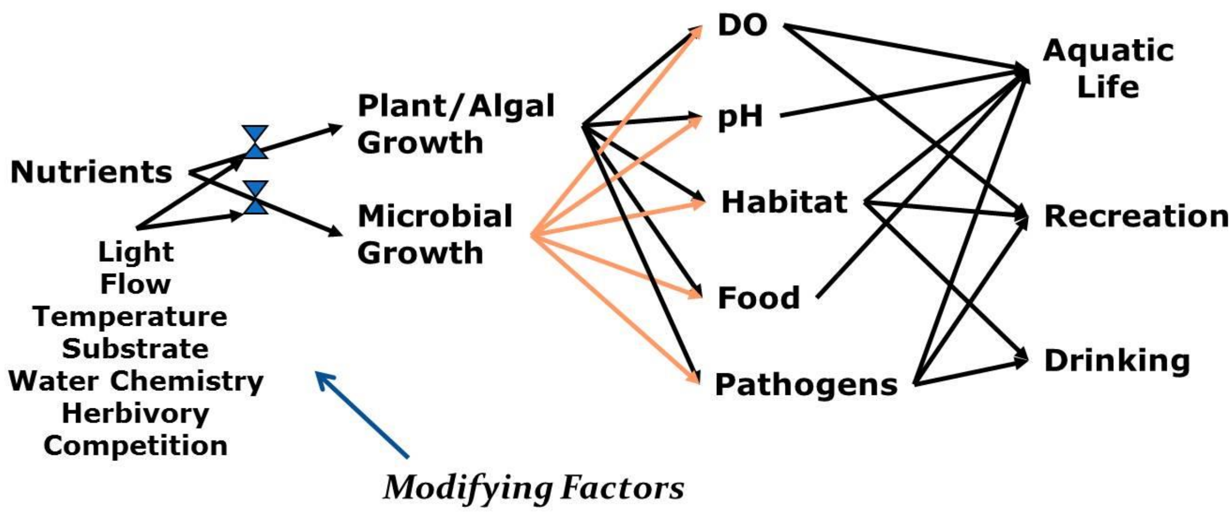

Figure 3. Simplified descriptive model depicting linkages between nutrients and designated uses (after Paul 2009).

To provide the data to support the development of NNC, DWQ conducted a statewide study that evaluated the effects of nutrients on Utah's streams including several ecological responses that can be used as water quality indicators. DWQ already measures several parameters that are related to nutrient-related problems (e.g., pH and DO); however, these responses can be insensitive to nutrient enrichment. To overcome this limitation, DWQ identified and measured several water quality indicators to be as proximate to nutrients as possible. Specifically, this study involved measures of ecosystem functions and existing measures of biological integrity that were measured at streams with varying nutrient conditions. These studies are described in detail in the *Technical Support Document: Utah's Nutrient Strategy* (Ostermiller et al. 2018) and summarized here in support of headwater NNC.

Candidate responses (water quality indicators) were selected after reviewing the ecological literature and in consultation with DWQ's nutrient technical subcommittee and academic researchers. Candidate responses were included for evaluation if they met two objectives. First, the nutrient response indicators had to be derived from well-established measures, supported by scientific literature. Second, the indicators had to be suitable for incorporation into Utah's routine monitoring and assessment programs. The selected indicators included five functional measures of condition and biological structure derived from two assemblages (macroinvertebrates and diatoms) (Table 2). Subsequent to DWQ's selection of these indicators, USEPA convened a workshop of national experts to discuss potential responses that were most sensitive to nutrient enrichment (USEPA 2014). Many of the most highly ranked responses selected by the USEPA Technical Advisory Panel (USEPA 2014) were already included in the DWQ investigation.

Table 2. Nutrient Thresholds Derived for Various Ecological Responses from Stressor-Response Modeling Efforts

Ecological Responses	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)
Functional Indicators		
Nutrient Limitation	0.42	0.080
Stream Metabolism		
Lower Threshold	0.24	0.026
Upper Threshold	1.28	0.090
Autochthonous Organic Matter Standing Stock		
Lower Threshold	0.24	0.026
Upper Threshold	1.95	0.590
Structural Indicators		
TITAN		
Sensitive Macroinvertebrates	0.18	0.011
Tolerant Macroinvertebrates	0.41	0.610
All Macroinvertebrates (nCPA)	0.41	0.015
All Diatom Taxa (nCPA)	--	0.045
Biological Assessments		
Macroinvertebrate O/E	0.43	0.045
ROC Thresholds O/E	0.32	0.030

Notes: nCPA = nonparametric change point analysis, O/E = the ratio between the number of observed species and the number of species expected, ROC = receiver operating characteristic, and TITAN = total indicator taxon analysis.

Study Design

DWQ collected most of the data to support NNC development with a study conducted in 2010. An important aim of the investigation was to ensure that collectively the sites encompassed the range of stream types found statewide. To meet this objective, DWQ collected data upstream and downstream of 8 publicly owned treatment works (POTWs) and at an additional 15 physically similar reference sites that were used to define healthy conditions (Figure 4). This design allowed DWQ to capture a gradient of nutrient conditions, as well as the influence of both nonpoint sources (upstream reaches) and point sources of nutrients. Ultimately, the design successfully included streams that were representative of the range of nutrient concentrations that occurs statewide (Figure 5).

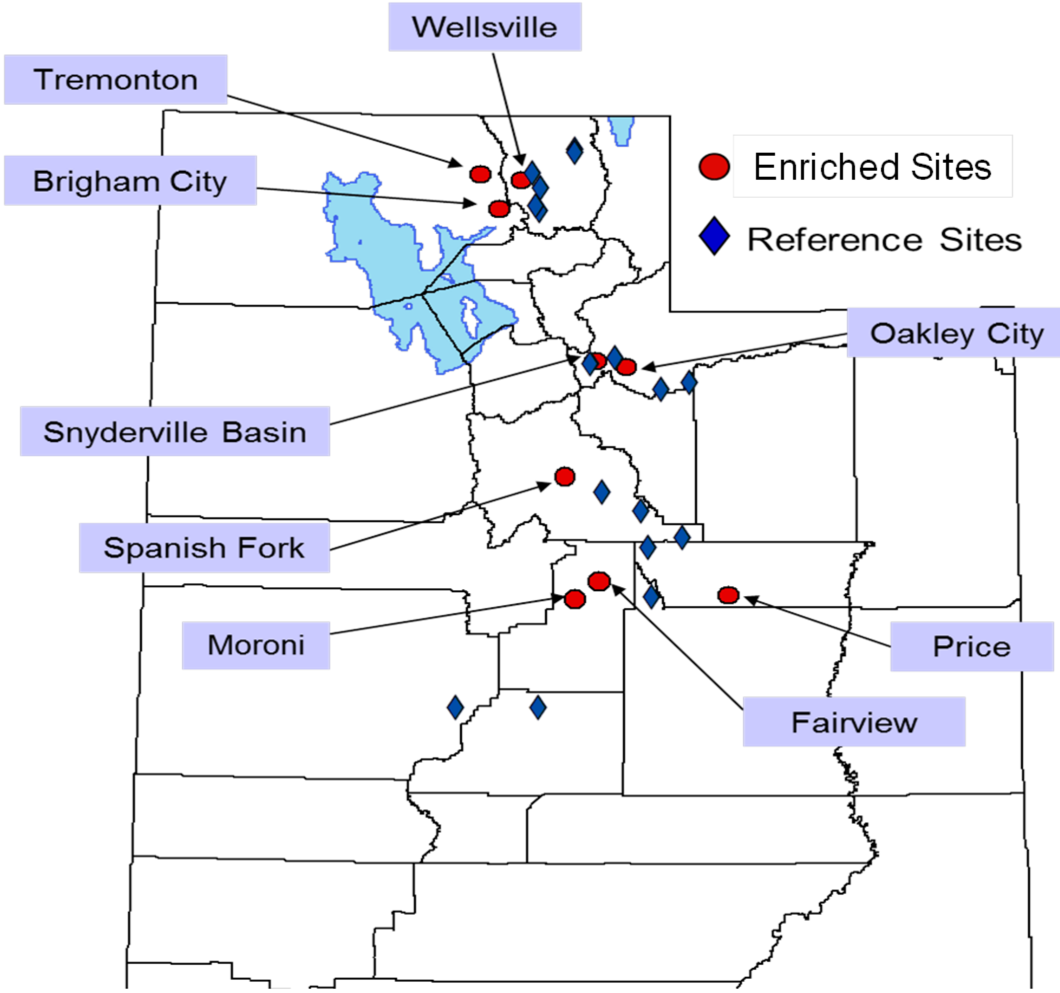

Figure 4. Map depicting locations of sites that were used for the stressor-response analysis.

Note: Enriched sites are a combination of two study reaches above and below a POTW discharge (labeled red circles)and vary with respect to the magnitude of nutrient enrichment. Reference sites represent minimally enriched stream locations and are represented by blue diamonds.

DWQ used empirical models to evaluate the relationships among stream N and P concentrations and various measures of potential ecological responses to nutrient enrichment. The three steps of these analyses were: classification, derivation of S-R models, and validation of model thresholds (see Ostermiller et al. 2018 for details). The objective of these analyses was to establish N and P concentration thresholds that best separated streams into2–3 condition classes based on their relative ecological response to nutrient enrichment for each of several different measures of ecological condition. The decision to define a limited number of condition classes for each indicator was made prior to data analysis based on previous observations that it is frequently easier to identify those streams in good and poor condition, than intermittent circumstances where deleterious responses are often more nuanced.

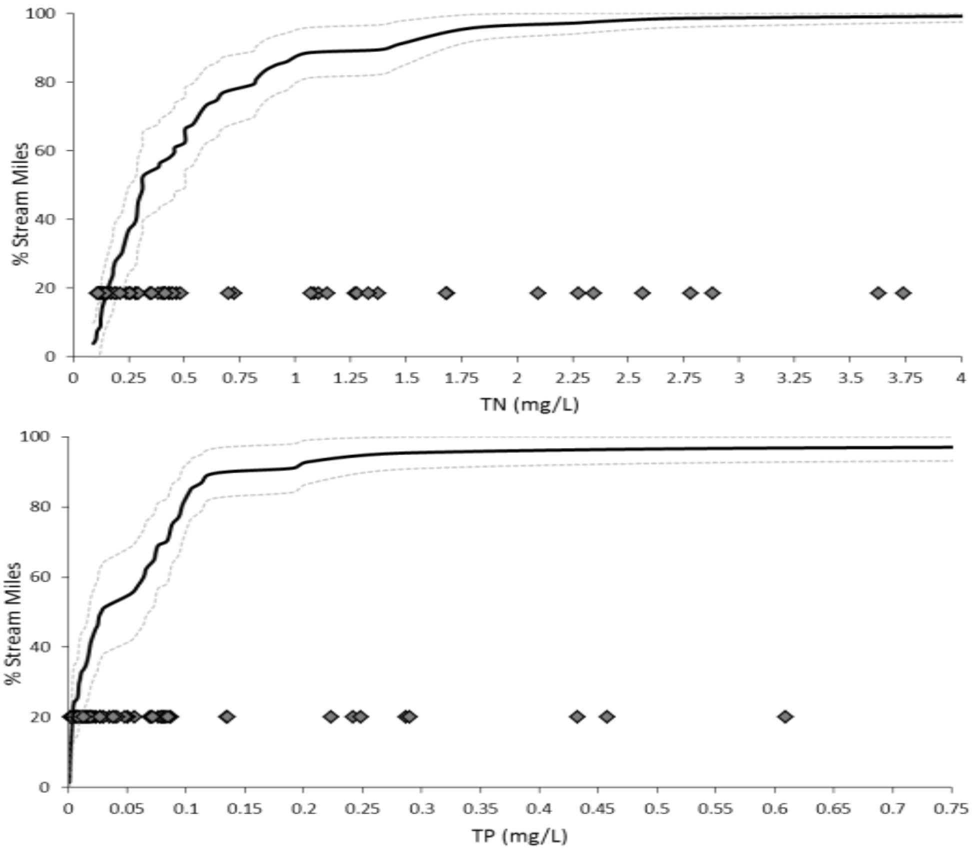

Figure 5. Nutrient concentrations at stressor-response study sites in comparison with statewide estimates.

Note: Solid black lines represent the cumulative frequency distribution of all Utah perennial streams. The data for these cumulative distribution functions (CDFs) were obtained from 50 randomly selected sites throughout Utah. The dashed lines depict the 95th percent confidence interval of distribution estimates for statewide average nutrient concentration (solid black line). Grey diamonds are the average nutrient concentrations obtained from the sites used in this functional response study. These plots do not include three high TN and four high TP sites because they exceeded the plot scale.

To generate the proposed NNC, DWQ combined all of the lines of evidence from all stressor-response relationships using decision rules that established three tiers of streams that vary with their extent of nutrient enrichment. A low enrichment tier was established that consists of streams where TN and TP are reflective of naturally-occurring conditions. At the other extreme, a high enrichment tier was established where human-caused enrichment has been relatively extensive. Streams that fall between these extremes were placed into a moderate enrichment tier. For moderately enriched streams ecological response thresholds were included to determine whether the nutrient enrichment resulted in any deleterious alterations to the condition of aquatic life uses. DWQ included an examination of multiple ecological responses to ensure that the NNC are protective of the biological integrity of headwaters. This approach also allows DWQ to select upper limits of the low enrichment tier that are conservative while also minimizing erroneous impairment determinations.

Summary of Findings

Classification

Addressing natural variation—in both background concentrations and ecological responses—remains a challenge for NNC development. Background nutrient concentrations vary as a result of physical and environmental factors such the mineral composition of soils and bedrock, soil erosion rates, organic matter inputs, channel type, and gradient (Smith et al. 2003). In fact, ambient stream nutrient concentrations can vary considerably among reference sites nationally (Lewis et al. 1999). In a recent review of national nutrient-concentration variation among reference streams, the 75th percentile of reference site TN varied from 0.13–1.19 mg/L, while TP varied from 0.009–0.170 mg/L (Evans-White et al. 2014). Moreover, differing environmental gradients can buffer or exacerbate ecological responses to nutrient enrichment, which means that failure to account for gradients can result in NNC that are either overprotective or underprotective of beneficial uses (Dodds and Welch 2000). Classification minimizes natural variation by systematically grouping streams with similar physical and environmental characteristics. DWQ is proposing NNC for headwater streams only as an initial classification step in Utah's Nutrient Strategy.

DWQ further assessed headwater streams to determine whether additional subclasses were needed to factor out the influence of natural variation on nutrient concentrations. To meet this objective, DWQ compiled numerous measures of landscape-level physical conditions (e.g., stream gradient, stream size, elevation, background lithology) that are known to be directly or indirectly associated with natural gradients in nutrient concentrations or ecological responses. Multivariate statistical techniques were used to divide headwater streams into two classes of streams—one class with 46 reference sites and another with 43—that were as different in these physical characteristics as possible (see Chapter 10, Ostermiller et al. 2018 for details). Nutrient concentrations from these two populations of streams were then compared. Results of this analysis showed that neither N nor P was statistically different between these two groups of headwater reference streams. Therefore, DWQ concluded that additional subclasses were not needed to establish NNC for headwaters (Figure 6). Finer-scale divisions of nutrient gradients may be useful or needed in the future, but existing data are currently insufficient to justify additional classes of streams. DWQ will continue to evaluate the need to further refine headwater criteria as additional data are collected through routine monitoring and assessment processes that accompany these NNC.

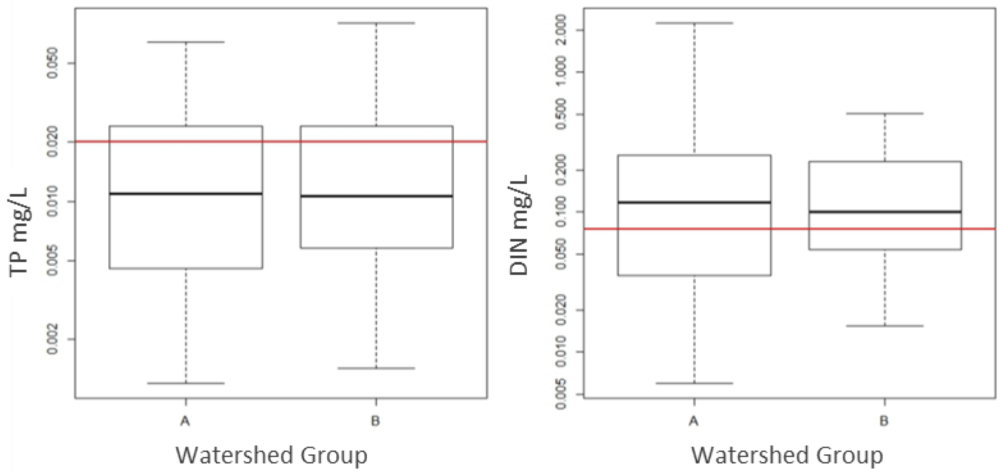

Figure 6. A comparison of nutrient concentrations between the two most physically distinct groups of headwater streams.

Note: Boxplots show distributions of total phosphorus (TP) and dissolved inorganic nitrogen (DIN) for two groups of headwater reference streams (A: n = 46, B: n = 43)) that were as physically distinct from each other as possible based on the results from k-means clustering. Important physical characteristics included: air temperature, precipitation, elevation, and soil characteristics. Data below red vertical lines are non-detects and were extrapolated using Kaplan-Meier survival analysis.

Derivation of Numeric Nutrient Criteria Thresholds

NNC for headwater streams need to be protective of uses, which means that indicators need to be sensitive enough to detect deleterious responses resulting from nutrient enrichment before they are severe enough to constitute and impairment to the protected use. As previously mentioned, there are many different and interrelated paths between nutrients and uses, and the most important routes can vary spatially and temporally. As a result, DWQ opted to derive thresholds from several functional, structural and frequency distribution indicators so that protective N and P concentrations could be selected on a weight-of-evidence basis. To accomplish this objective, S-R statistical models were developed and thresholds subsequently established for all possible combinations of each stressor (TN and TP) and all responses (Figure 7).

Collectively, the N and P thresholds established from these models fall within a narrow range of nutrient concentrations. Most of the thresholds for TN are between approximately 0.30 and 0.70 mg/L, and most of the thresholds for TP are between 0.020 and 0.060 mg/L (with one as high as 0.08) (Figure 7). These are regional generalizations, so each of these thresholds is bounded by upper and lower confidence estimates. Accounting for this variance, the overlap among indicators is even more apparent. Any value within these ranges of protective conditions could potentially be justified as an appropriately protective concentration of TN or TP.

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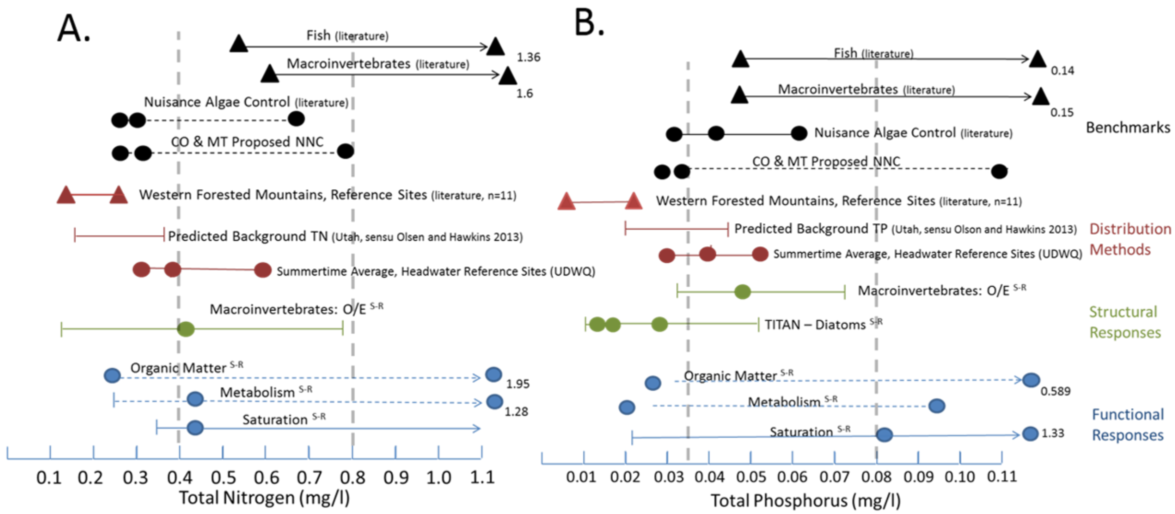

Figure 7. Numeric nutrient criteria thresholds derived from numerous sources for total nitrogen (panel A) and total phosphorus (panel B), along with the proposed numeric nutrient criteria for these nutrients.

Notes: Lines bracketed by triangles indicate the omission of numerous intermediate thresholds (dots). The graphics are colored to demarcate different categories of thresholds. Blue denotes functional responses. Green denotes structural responses (DWQ calculations). Red denotes thresholds derived using frequency distribution methods: the bottom red dots indicate the 75th, 90th, and 95th percentiles of the summertime average of Utah reference sites; the middle red line denotes background concentrations obtained from an empirical model that predicts background concentrations from natural environmental gradients; and the top red line denotes other distribution methods from reference site distributions in USEPA Nutrient Ecoregion II (Evans-White et al. 2014). Black denotes broad benchmarks for other proposed numeric criteria from USEPA Region 8 (the bottom black line) and values obtained from primary literature (the top three black lines; Evans-White et al. 2014). The vertical dotted lines are the proposed numeric nutrient criteria thresholds presented here.

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Ecological Confirmation of Empirical Thresholds

The thresholds derived from S-R models are based on the statistical distributions of nutrients and responses, which does not necessarily mean that they are ecologically relevant. The fact that the thresholds derived from different responses are similar provides evidence that they are ecologically meaningful because several different indictors on biological integrity are simultaneously altered over a relatively narrow range of enrichment. DWQ took this analysis a step further wherever possible by evaluating the thresholds against other related but independently derived measures of water quality. The functional measures of gross primary production (GPP), ecosystem respiration (ER), and organic matter standing stocks are all related to the production or consumption of oxygen; instantaneous measures of DO corresponded to excursions below the 30-day average DO criterion (Figure 8). Specifically, when ER or organic matter exceeded thresholds, appreciably more DO observations fell below this water quality benchmark. These DO benchmarks are conservative because instantaneous values of DO cannot directly assess a criterion that is expressed as a 30-day average. Nevertheless, these comparisons suggest that conditions at or below the ER threshold (5 g O_2/m^2/day) are protective against potentially stressful conditions to stream biota because the proportion of observations changes from near zero to approximately 40% when measurements are higher in the range of 6–9 g O_2/m^2/day.

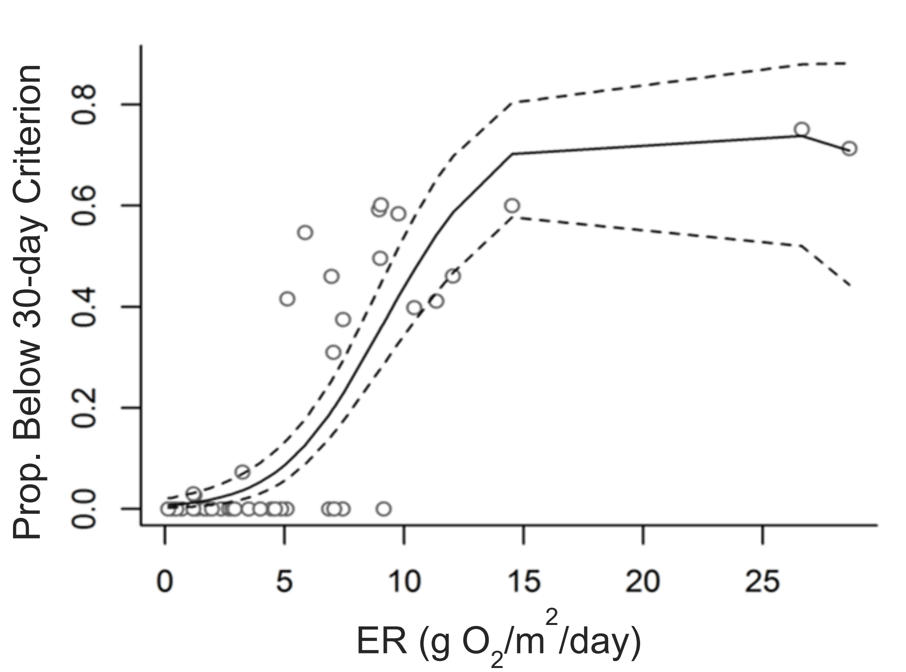

Figure 8. Relationship between ecosystem respiration and the proportion of site dissolved oxygen observations that fell below Utah's 30-day average dissolved oxygen criterion.

For structural responses, nutrient thresholds were compared against independent measures of biological condition currently used by DWQ to assess the conditions of streams (the ratio of the number of species observed to the number of species expected to be observed, O/E). Again, the data closely matched these independent measures of stream condition. Moreover, the corresponding nutrient thresholds that were established using these biological assessments resulted in a fair balance between false positive and negative assessment errors, as determined from previously established impairment thresholds for O/E.

While it is not possible to determine cause-effect relationships with regional S-R models, the collective results—particularly when coupled with benchmarking from the literature and other proposed NNC—supports the validity of S-R derived thresholds for headwater streams. However, it is equally important to note that there were site-specific exceptions to general patterns for every indicator evaluated. Significant influences of important covariates (i.e., stream gradient, channel shading) were observed for several responses. These observations highlight the importance of simultaneously examining both nutrients and responses to avoid either missing sites with nutrient-related problems or making erroneous impairment conclusions.

Frequency Distribution Methods

As previously mentioned, another approach to NNC development involves the derivation of NNC from the distribution of observed TN and TP among reference streams (USEPA 2000). The most common metrics used to establish NNC from these distributions are the 75th, 90th, or 95th percentiles. These values were calculated to provide an additional line of evidence in support of the S-R thresholds (Table 3). In all, 45 reference sites with TP summertime data were evaluated, and 43 reference sites were evaluated for TN levels. However, many of the potential TN reference samples lacked organic N data, which required calculating predicted TN (PredTN) from total inorganic N (linear regression, $r^2 = 0.92$, $p < 0.001$). For each of these sites, summertime averages were calculated with all data collected from June through September across the most recent nine years of available data. Several percentiles were then calculated from these growing season average reference site distributions (Table 3). These thresholds align well with those derived from S-R relationships, providing further support for the headwater NNC proposed by DWQ.

Table 3. Distributions (Percentiles) of Growing Season Average Total Phosphorus and Total Nitrogen Concentrations in Headwater Reference Streams

Percentile	Total Phosphorus (mg/L)	Predicted Total Nitrogen (mg/L)
75th	0.027	0.29
90th	0.037	0.38
95th	0.053	0.61

Effects of Nuisance Algae on Recreation Uses

Previous investigations have observed that excessive stream algae creates conditions that people find undesirable (Supplee et al. 2009). This human dimension warranted exploration by DWQ given the importance of headwater watersheds to outdoor recreation. Utah's Office of Outdoor Recreation estimates that recreation contributes $12 billion/year and over 100,000 jobs to Utah's economy. Maintenance of stream aesthetics is an important aspect of the general quality of life for Utahns—more than 70% of Utah citizens recreate on or around streams, many of them in headwater watersheds. These streams are also critical culinary water sources in a state that is the second driest in the country with one of the fastest rates of population growth. The importance of these waters has been codified in the Utah Administrative Code Rules R317-2-6.2 and R317-2-7.2.

DWQ, in conjunction with a larger economic study, surveyed randomly selected citizens (1,411 respondents) to evaluate the potential impact of nuisance algae on recreational uses (CH2MHill 2012). Each survey included photographs of streams with varying quantities of algae growth. For each photograph, citizens were asked whether the conditions represented "desirable" recreation conditions. With remarkable consistency, citizens reported a drop in desirable conditions as algae increased from 110 to 200 mg chl-*a*/m^2 (Figure 9). Based on these results, and in accordance with benchmarks developed by other independent investigations in the literature, DWQ proposes a benthic algae concentration of 125 mg chl-*a*/m^2 as a numeric criterion protective of recreational uses in headwater streams. This criterion is protective of degradation to recreational uses because it is above the benthic chl-*a* concentration for which nearly all respondents indicated desirable conditions but below the point at which respondents started indicating that the depicted stream conditions were undesirable.

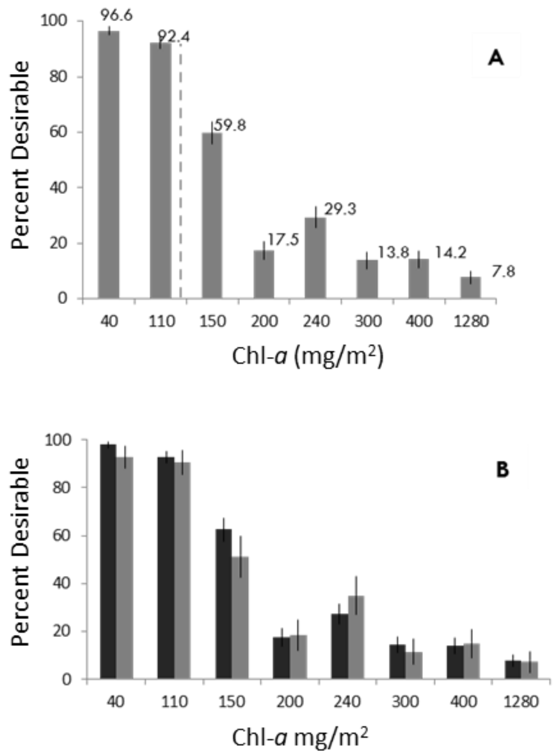

Figure 9. Results of Utah's survey regarding undesirable benthic algae in recreational waters with proposed criterion depicted as a dashed, vertical line.

Note: (A) Percent desirable benthic algae responses from all Utah survey participants. (B) Percent desirable benthic algae responses from user (black) and non-user (grey) groups showing similarity in responses. Error bars indicate 95% confidence intervals.

RATIONALE BEHIND PROPOSED HEADWATER NUMERIC NUTRIENT CRITERIA

This section summarizes the rationale behind the NNC for Utah's headwater streams and ends with a discussion of how the Utah NNC compare with criteria proposed elsewhere and with results published in peer-reviewed scientific literature. Criteria are proposed for TN and TP at two different concentrations that define three tiers of streams that differ with respect to the extent of nutrient enrichment. The higher enrichment tier is considered to be reflective of human-caused enrichment of sufficient magnitude that responses are not required for identifying an impairment to aquatic life uses. Streams where TN and TP fall below the lower enrichment threshhold are interpreted to be indistinguishable from naturally occurring conditions and in full support of aquatic life uses unless other evidence suggests otherwise. Streams that fall between the upper and lower thresholds will be evaluated in combination with ecological responses. For all proposed criteria, a rationale is provided for the magnitude (concentration), duration (averaging period), and recurrence interval (acceptable number of exceedances). Technical details that support this rationale are available in the *Technical Support Document: Utah's Nutrient Strategy* (Ostermiller et al. 2018).

Elsewhere, NNC have been proposed that rely exclusively on water column nutrient concentrations. However, overreliance on chemical constituents alone may lead to underprotection of streams because biological uptake lowers ambient nutrient concentrations, at least on a temporary (i.e., within-season) basis. When water column nutrients are incorporated into algal or plant cells, the nutrients can be captured with samples that quantify total (both organic and inorganic) N and P. However, in small to moderate size streams most primary production occurs on the streambed, which TP or TN water column samples may miss. The end result is that water column concentrations can sometimes be deceptively low in situations where primary production is high. As a result, DWQ proposes that appropriately protective criteria should include both concentrations of N and P and indicators that measure autotrophic and associated heterotrophic responses to nutrients. Another advantage of simultaneously measuring the cause of cultural eutrophication (nutrients) and ecological responses is that these data can identify locations where regional headwater NNC may need to be modified on a site-specific basis because natural conditions are either protective of water quality or exacerbate deleterious ecological responses.

Despite the advantages of combined criteria, there are circumstances where nutrient data are available but ecological response data are not. As a result, DWQ proposes the TN and TP criteria in the NNC moderate enrichment tier to not be assessed with respect to nutrients until sufficient data are available to determine whether or not deltetarious alterations to designated uses has occured. When such circumstances are identified, DWQ will prioritize further evaluation of the stream to make this determination. This will allow the most heavily nutrient-impacted headwater streams to be prioritized for further investigation. The combination of these enrichment levels (low nutrient concentrations with coupled ecological response data and higher concentrations without ecological response data) allows DWQ the flexibility necessary to ensure that nutrient-related water quality problems do not degrade uses in any headwater stream while helping DWQ prioritize monitoring and watershed planning resources.

Other considerations behind these NNC were pragmatic: the criteria are expressed in a manner that allows them to be evaluated with data that are readily available from routine water quality monitoring programs. DWQ has defined a monitoring and assessment strategy and minimum sample requirements to help ensure that both nutrient and response data are available (see the section "Programmatic Implications" below).

Numeric Criteria for Nitrogen and Phosphorus

The Importance of Both Nitrogen and Phosphorus

An important consideration in DWQ's NNC relates to the relative importance of N and P in controlling ecological responses. There is considerable evidence from nutrient-diffusing substrates (Elsner et al. 2007) and streamside experimental additions (Rier and Stevenson 2006) that streams are often co-limited by N and P—the addition of N *and* P may lead to greater algal responses than the addition of either nutrient alone. This is particularly true across broad spatial and temporal scales. Using nutrient-diffusing substrate methods, DWQ found co-limitation to be the most common condition in study streams (Ostermiller et al. 2018), although, these results need to be confirmed with alternative experimental methods. In streams there is a range of total algal biomass N:P of approximately 6–10 for which co-limitation is likely. As N:P drops below 10, N becomes limiting, whereas P becomes limiting as N:P exceeds 17 (Smith 1982, Dodds 2003). Different algal assemblages can exhibit vastly different N:P ratios, and limitation can be difficult to determine from these estimates alone. One reason for natural variation in N:P relates to physical differences among watersheds. The N:P of underlying soil and lithology varies from place to place, as does the extent to which nutrients are mobilized (Olson and Hawkins 2013). DWQ's proposed criteria acknowledge these natural differences among streams but are broadly protective by including both N and P.

Differences in N:P among streams can also be biologically driven based on differing nutrient requirements among algal species. Controlling exclusively for P is complicated by the fact that some species are capable of storing P in excess of their immediate requirements (luxury uptake), which would offset the environmental benefits of P control efforts. For example, *Cladophora,* a common nuisance alga in Utah, has been shown to have increasing concentrations of tissue P as concentrations decline in surrounding waters (Lohman and Priscu 1991). Other species are capable of "fixing" N from the environment, which moves streams toward P-limitation. The presence and relative dominance of different algal species within a stream varies temporally. Moreover, different algal species favor different microhabitats within streams. These factors, coupled with varying nutrient demands among algal species, mean that the relative importance of TN and TP varies both spatially and temporally. While additional research is needed, there is increasing evidence that the expanding nuisance algae

Didymosphenia is exacerbated by high N:P (mean of 31:1, range = 98 to 3.7:1; N = 5, Whitton and Ellwood 2009), in hydrologically stable streams.

It is important to note that human sources of nutrient enrichment in headwater streams result from either atmospheric deposition or other nonpoint sources. In reality, best management practices (BMPs) that address most of these diffuse sources are equally effective at reducing both nutrients. If it were possible to reduce one nutrient in favor of another it would be more important to determine exactly which nutrient was limiting by using appropriate autotrophic or heterotrophic bioassays conducted over the course of several seasons. If circumstances arise where such considerations are important, specifics can be evaluated through follow-up investigations that are routinely conducted following impairment determinations.

For these reasons, DWQ's headwater NNC are more likely to protect designated uses if they include both N and P, and the specific N:P of these criteria should not favor limitation of one nutrient over the another. DWQ also proposes that these criteria should be set for total N and P. Elsewhere, NNC are sometimes proposed for TIN or soluble reactive P (SRP), because these inorganic forms of nutrients are immediately available to aquatic plants and algae. While this may be true over relatively small spatial and temporal scales, organic forms of nutrients are cycled fairly quickly into inorganic forms (Dodds 1993). As a result, criteria based on TN and TP better capture the risk to aquatic biota over the spatial and temporal scales of management concern and are incorporated into the duration and frequency standards proposed by DWQ. That said, DWQ strongly recommends that data on all nutrient constituents are collected whenever possible; DWQ will continue to collect such data because knowing the constituents of TN and TP is critical when interpreting water quality data (see the "Monitoring" subsection in the "Programmatic Implications" section below).

Magnitude of Total Nitrogen and Total Phosphorus

Both upper and lower numeric TN and TP criteria are appropriately protective of the Class 3A and 3B aquatic life uses in headwater streams for the following reasons:

- The lower concentrations are consistent with the 90th percentile of the growing season mean among reference sites, which have been used to support criteria elsewhere.
- All proposed concentrations are within the range of values—thresholds and associated confidence intervals—associated with fully supporting conditions as measured with biological assessments (structural indicators).
- The lower threshold is at or near the relatively good to fair conditions that were defined with functional response indicators, and the upper threshold falls below the fair to poor condition thresholds.
- While there is no general agreement about what constitutes excess algae, most researchers suggest that appropriate values lie somewhere between 125–200 mg chl-*a*/m^2. Calculations derived from regional estimates (Dodds et al. 2009 suggest that the lower values should, on average, prevent growth in excess of the lower end of this

range while the upper concentrations should not allow growth in excess of the upper end of this range.

- All proposed concentrations are below levels where primary production was, on average, saturated with respect to nutrients, which indicates that other factors were limiting algal growth at these sites.

NUMERIC NUTRIENT CRITERIA

DWQ identified three levels of nutrient categories (TN and TP) for Utah's headwater perennial streams.

Level 1: Low Enrichment

Streams at or below these concentrations for *both* TN and TP are considered to be supporting aquatic life uses.

Total Nitrogen (as N) < 0.40 mg/L

Total Phosphorus (as P) < 0.035 mg/L

Level 2: Moderately Enriched

Streams in this range of nutrient concentrations require documentation of no deleterious ecological responses before making a determination that aquatic life are supported.

Total Nitrogen (as N): 0.40–0.80 mg/L

Total Phosphorus (as P): 0.035–0.080 mg/L

Level 3: Highly Enriched

Streams with concentrations above this range of nutrient concentrations are not supporting the aquatic life use.

Total Nitrogen (as N) > 0.80 mg/L

Total Phosphorus (as P) > 0.080 mg/L

Note: All of the above concentrations are based on averages from ≥ 4 samples during the period of algae growth through senescence.

Duration and Frequency

Duration

The proposed NNC are based on an arithmetic average of water column TN and TP during the period of algae growth through senescence.

Frequency

The summertime seasonal average TN and TP criteria shall not be exceeded.

How will Seasonal Averages be Calculated?

Water column nutrient samples are variable and seasonal averages should be based on as many samples as possible. Seasonal averages are based on a minimum sample size of ≥ 4 samples collected in a single growing season, which is defined as the period of algae growth following spring runoff to algae senescence in the autumn. DWQ will use an arithmetic mean and not alternative averaging methods that down-weight outliers (e.g., geometric mean, median) because in some streams pulses of nutrients from runoff represent a considerable contribution to the total loads of N and/or P.

Why Focus on the Summertime Growing Season?

DWQ proposes that NNC for TN, TP, and filamentous algae (see below) apply to the summertime growing season (post-runoff algae growth through autmn senescence) for two reasons. First, most of the deleterious nutrient problems are the consequence of longer-term nutrient inputs that are observed during the summertime growing season. This averaging period also aligns with the recreation season defined in Utah's assessment methods for recreation criteria.

Why Not to be Exceeded?

DWQ proposes that a single seasonal average value is sufficient for interpretation of the nutrient concentration components of the NNC. One concern with the conservative nature of "not-to-exceed" criteria is that atypical stream conditions may result in either false positive or false negative assessments. The risk of such errors is unlikely for the headwater NNC. First, as with all standards, DWQ may exclude samples collected under extremely high or low water conditions when calculating summertime averages of TN or TP (UAR 317-2-9). Second, the incorporation of biological responses into these NNC and the ongoing independent assessment of other parameters (see below) provide DWQ with multiple lines of evidence to use when identifying water quality problems.

Bioconfirmation Criteria: Stream Respiration and Benthic Algae Growth

There are many potential paths between nutrients and potential degradation of aquatic life uses, but they are all initiated by the influence of nutrients on autotrophic plants or algae or on heterotrophic microbial populations (Figure 3). These proposed bioconfirmation criteria capture alterations to these two principal nutrient-related assemblages, which in turn address several alternative paths between nutrients and effects on aquatic life uses. The specific thresholds for ecological responses that DWQ proposes are consistent with those that were recommended as the most sensitive and directly linked to nutrients by a recently convened USEPA Technical Advisory Panel (USEPA 2014). The stressor-response investigations included other responses that could potentially have been used as additional lines of evidence in the NNC, but these were either impractical to integrate into routine data collection activities (e.g., organic matter standing stocks) or unable to be used in the context of assessing aquatic life use support (e.g., NDS). Existing numeric criteria also exist that quantify, in part, the effects of nutrient enrichment (e.g., pH, DO) and nutrient enrichment will continue to be explored as a potential cause for any impairments that are identified. Consideration was also given to including O/E as a nutrient-related response, but a determination was made to keep these assessments independent. However, this decision does not preclude the exploration of nutrient enrichment as a potential causal factor for any impairments that are identified.

AQUATIC LIFE USES

The intermediate enrichment TP and TN concentrations will be combined with the following responses, which are not to be exceeded in headwater perennial streams with Classes 3A or 3B aquatic life use designations
(UAR R317-2).

Plant/Algae Growth

> 1/3 aerial cover of filamentous algae cover[a]
OR
Gross primary production (GPP) of > 6 g O_2/m^2/day[b]

Microbial Growth

Ecosystem respiration (ER) of > 5 g o_2/m^2/day[b]

Notes:

a) *Filamentous algae cover means patches of filamentous algae > 1 cm in length or mats > 1 mm thick. Estimates should be reach-scale averages with at least three measures from different habitat units (i.e., riffle, run) using quantitative and repeatable visual cover estimates. Applicable during the period of algae growth through senescence.*

b) *Daily whole stream metabolism using open channel methods. GPP measures are based on the amount of oxygen produced by autotrophs, and ER measures are based on the amount of oxygen consumed by plants and microorganisms. Applicable to during the period of algae growth through senescence.*

Why filamentous algae cover?

One of the most common ways that excessive production is manifest in Utah's headwater streams is a shift from an algal assemblage dominated by diatoms to one dominated by less desirable filamentous algae, particularly *Cladophora*. Filamentous algae are a less desirable food resource for most stream grazers (Hicks 1997). When they become the dominant taxon they degrade the habitat of higher organisms by trapping fine sediment, subsequently filling interstitial spaces within the stream benthos. When this occurs, it directly affects fish reproduction by decreasing the survival of juvenile fish (Dodds and Gudder 1992). As previously noted, excessive amounts of filamentous algae also degrade stream aesthetics, creating conditions that are undesirable to recreational uses.

Several experimental and field-based studies have shown that filamentous algae cover is positively correlated with increasing nutrient concentrations. Streamside nutrient-enrichment experiments have documented that algal biomass increased with increasing nutrient additions (Bothwell 1989, Rier and Stevenson 2006). Stevenson and colleagues (2006) found that the probability of getting a filamentous algal cover of 20–40% increased when TP was > 0.03 mg/L or TN was > 1 mg/L in Midwest United States streams considered susceptible to filamentous algae growth. However, this study also noted that filamentous algae was absent at many streams with high nutrients. Others have noted that whether or not filamentous algae cover reaches levels of potential concern is also dependent on other stream characteristics such as canopy cover, stream temperature, stream size, and hydrology (Busse et al. 2006, Dodds and Oakes 2004, Riseng et al. 2004). As a result, the amount of filamentous algae cover within a given stream can vary seasonally and from year-to-year (Dodds and Gudder 1992, Francoeur et al. 1999). In essence, while the presence of excessive amounts of algae is ecologically meaningful, the absence of high levels of algae during any single observation is not particularly informative.

The derivation of the filamentous algae NNC threshold was semi-quantitative. DWQ supports that nutrients must be controlled to prevent filamentous algae from becoming the dominant form of benthic autotrophs, which is defined as >50%. As discussed elsewhere in responses to this section, this is because extensive filamentous algae cover are more likely to be associated with nutrient enrichment and also because they represent a greater threat to aquatic life uses. Given this determination, any value less than 50% is considered to be protective. Filamentous algae blooms can occur in relatively unenriched streams with stable flows, but they tend to have a more limited spatial and temporal extent. To avoid making too many false impairment determinations due to natural filamentous algae accumulations, DWQ used 20% to demarcate an upper limit of naturally-occurring conditions. DWQ then met with a technical review team and the consensus was that ⅓ , a value approximately midway between 20-50%, was the most appropriate for balancing false positive and false negative decision errors. DWQ identified a criterion of maximum filamentous algae cover of 1/3 of the stream bed. While this number is at the upper end of concentrations that others have suggested as protective of stream aquatic life uses, DWQ has established this threshold as protective of stream conditions because it represents the maximum filamentous algae concentration that is observed on any single collection event. This selection also acknowledges the paucity of percent filamentous algae cover that is currently available for Utah streams. This criterion, among others, will be reevaluated as additional data are collected and will be adjusted if it is found to be either overprotective or underprotective of the aquatic life uses in Utah's perennial headwater streams.

Why gross primary production?

Excessive plant or algal growth is one of the principal deleterious consequences of excess nutrients in stream ecosystems (Horner et al. 1983, Biggs 2000). GPP and percent filamentous algae are different and complementary measures of potential increases in the abundance of plant and algal growth resulting from nutrient enrichment. GPP measures net primary production via reach-scale estimates of the amount of oxygen produced by plants and algae on a daily basis. Worldwide, several researchers have suggested that GPP is among the best measures of nutrient response in streams because it quantifies a fundamental ecosystem process at an appropriate spatial scale (Bunn et al. 1999, Young et al. 2008). Fellows and colleagues (2006) evaluated several direct and indirect measures of stream primary production and concluded that indirect measures of production were less sensitive than GPP in identifying streams with degraded conditions. DWQ's proposed threshold of 6 g O_2/m^2/day was empirically derived as the GPP best differentiated streams in low and moderate enrichment classses (see Ostermiller et al. 2018, Chapter 5 for details). Streams in the low enrichment class had ambient nutrient concentrations within the range of those observed at reference sites. Use support is presumed under reference conditions, so the corresponding GPP rates can be assumed to be similarly protective. DWQ's proposed threshold is also consistent with the level at which other investigations have suggested that nuisance algae begin to become a problem for aquatic life uses (Young et al. 2008). To be protective, DWQ also proposes that this value should not be exceeded—meaning that the threshold cannot be exceeded on any day during deployment—because DWQ considers values higher than this threshold to constitute an impairment to aquatic life uses.

Why both gross primary production and filamentous algae cover?

GPP and filamentous algae cover have strengths and weaknesses as indicators of excessive primary production. GPP measures a fundamental ecosystem process that is directly tied to nutrients, but this response has several disadvantages. For instance, it is sometimes not possible (or practical) to make whole stream metabolism calculations at streams with an insufficient diel change in DO to calculate physical reaeration. Another limitation of GPP is that this measure requires deployment of specialized equipment, which makes it is logistically impossible to always have GPP data coincident with TN and TP samples. These same logistical constraints make GPP ill-suited for capturing within-season changes in primary production.

In contrast, filamentous algae can be consistently measured during routine water quality sample collections, making it an ideal response to capture within-season changes in nuisance algal abundance. Additionally, filamentous cover measures do not require the use of specialized equipment because the equipment (i.e., grids, viewing boxes) can be easily and inexpensively manufactured. Filamentous algae cover measures have disadvantages as well. In some streams, excessive filamentous algae cover is not observed until later in the season. Similarly, spates can scour filamentous algae from streams, which means that excessive algae cover might be missed on any given sampling event.

DWQ has determined that the use of both GPP and filamentous algae responses will allow more accurate identification of headwater streams with nutrient-related problems. GPP provides a daily measure of primary production that is integrative over smaller temporal scales, whereas filamentous algae cover is an ecological response that is more practical to measure across a growing season. The use of both indicators also provides greater flexibility when integrating the collection of nutrient-related problems into ongoing monitoring and assessment programs.

Why ecosystem respiration?

Increased plant and algae growth caused by excess nutrients can cause low nighttime DO—and high daytime pH—levels that are harmful to both mature and juvenile fish and invertebrates (Welch et al. 1992). In the case of DO, these problems occur because the plants and algae associated with elevated primary production eventually die and become a food source for fungi and microbes, which increase in abundance and decrease oxygen via normal metabolic processes. In streams where physical reaeration is naturally low, nighttime oxygen consumption (respiration) can exceed reaeration, which subsequently causes DO to decline, especially at night when plants and algae are not producing oxygen via photosynthesis. Whole stream ER captures this important stream function by quantifying the amount of oxygen consumed by stream organisms on a daily, per area basis. DWQ's proposed ER of threshold is 5 g O_2/m^2/day because this is the level that, on average, distinguished between low and moderately enriched streams (see Ostermiller et al. 2018, Chapter 5 for details). Because streams in the low enrichment class had nutrient concentrations within the range of ambient reference condition, it was assumed that the corresponding ER rates would similarly be protective of aquatic life uses. This proposed response criterion was also consistent with circumstances where the majority of instantaneous DO readings fell below screening values—Utah's 30-day DO criterion of 6.5 mg/L for all life stages (Figure 8). Interestingly, this value is also consistent with values proposed by other investigators as indicators of stream health (Bunn et al. 1999, Fellows et al. 2006, Young et al. 2008). As with GPP, this value was established at the point where, on average, streams shift from good to fair condition. This component of the NNC is intended to interpret as a "not-to-be-exceeded" value to protect aquatic life uses; the conservative nature of this recurrence interval is another element of the criterion that provides additional protection for aquatic life uses.

What about the other nutrient-related responses?

DWQ maintains that the use of ambient nutrient thresholds coupled with the proposed ecological responses covers (or blocks) all important response pathways between nutrients and aquatic life uses; however, it is also important to note that DWQ will continue to independently measure and assess other related water quality criteria. For instance, pH and DO will continue to be assessed against Utah's numeric criteria for these parameters. The accuracy with which these parameters can be assessed will likely improve with the additional high frequency data measures required for metabolism calculations. Both DO and pH can vary extensively on a diel basis, which complicates interpretation of instantaneous measures that are currently collected with water quality grab samples. DWQ will also continue to measure several water quality indicators that quantify the condition of stream habitats and the health of stream assemblages (see the "Monitoring and Assessment" section below for additional details). The simultaneous measures of these independent water quality criteria, coupled with the combined NNC and responses proposed in this document, will provide DWQ with tools to identify and address nutrient-related water quality impairments in headwater streams.

Numeric Nutrient Criteria for Protection of Recreational Uses

RECREATION USES

Recreational uses in headwater streams (Class 2A and 2B, UAR R317-2-6) will be protected with the following criteria that are not to be exceeded at any time:

Benthic Algae: > 125 mg chl-*a*/m^2
or
> 49 g AFDM/m^2

The proposed recreation benthic algae concentrations were derived from the previously mentioned survey and the reduction in aesthetics that Utahns reported. DWQ selected 125 mg chl-*a*/m^2 to preclude concentrations of 150 mg chl-*a*/m^2, which was the level at which desirable conditions started to decline (Figure 9). A degradation of recreational uses occurs when people choose not to recreate in a stream due to degraded aesthetics. Given the importance of recreation to Utah's economy, DWQ has determined that guarding against a degradation of recreational uses is appropriate. The data necessary to support these criteria have already been collected in conjunction with DWQ's Tier 1 Monitoring Program (see discussion in the "Programmatic Implications" section).

In making these determinations, DWQ acknowledges that there may be circumstances where a particularly productive and important fishery requires higher productivity than normal to continue support of this important recreational use. If such circumstances arise, DWQ will collaborate with Utah's Department of Natural Resources to determine an appropriate balance between the needs of the fishery, aesthetics, and the long-term support of the ecosystem. If appropriate, these recreational criteria will subsequently be modified, provided that all local and downstream uses will remain protected.

Summary of Proposed Numeric Nutrient Criteria

In summary, DWQ proposes a three-tiered NNC to protect aquatic life uses in headwater streams defined by two nutrient concentration thresholds (Table 4). A low enrichment tier is established for streams where ambient nutrient concentrations fall below the lower criteria of 0.4 mg/L for TN and 0.035 mg/L for TP; sites in this tier are considered to be indistinguishable from reference condition and, under such conditions, ecological responses are generally not needed to evaluate eutrophication problems. In moderately enriched streams, where TN or TP fall between the upper and lower thresholds, interpretation of the NNC requires evaluation of ecological responses.   Streams with ambient nutrients in exceedence of the upper NNC thresholds of 0.80 mg/L for TN and 0.080 mg/L for TP are place in the high enrichment NNC tier and responses are not required under such conditions to conclude that nutrient enrichment is a water quality problems in these streams. These upper thresholds will allow DWQ to identify headwater streams with nutrient-related problems in circumstances where ecological response data are unavailable.

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Table 4. Numeric Nutrient Criteria and Associated Ecological Responses (Bioconfirmation Criteria) Proposed to Protect Aquatic Life Uses in Antidegradation Category 1 and 2 (UAC R317-2-12)[f] Headwater Perennial Streams

Low Nutrient Enrichment at Headwater Streams: No Ecological Responses			
Summertime Average Nutrients			Assessment Notes
TN < 0.40[a,b]	TP < 0.035[a,b]		Fully supporting aquatic life uses if the average of ≥ 4 summertime samples for both TN and TP fall below the specified nutrient concentrations. However, it is not supporting aquatic life uses, cause unknown, if the ecological responses specified for moderate enrichment streams are exceeded. Sites with fewer samples, or those without TN and TP growing season averages, will not be assessed for nutrients.
Moderate Nutrient Enrichment at Headwater Streams and Ecological Responses			
Summertime Average Nutrients		Ecological Response	Assessment Notes
TN 0.40–0.80[a]	TP 0.035–0.080[a]	Plant/Algal Growth[c] < 1/3 or more filamentous algae cover[d,e] OR GPP[c] of < 6 g O_2/m^2/day OR ER[c] < 5 g O_2/m^2/day	Headwater streams within this range of nutrient concentrations will be considered impaired (not supporting aquatic life uses) if <u>any</u> response exceeds defined thresholds. Streams <u>without response data</u> will be listed as having <u>insufficient data</u> and prioritized for additional monitoring if either TN or TP falls within the specified range.
High Nutrient Enrichment at Headwater Streams: No Ecological Responses[e]			
Summertime Average Nutrients			Assessment Notes
TN > 0.80[a,b]	TP > 0.080[a,b]		Streams over these thresholds will initially be placed on Utah's Section 303(d) list as threatened. Threatened streams will be further evaluated using additional data such as nutrient responses, biological assessments, or nutrient-related water quality criteria (e.g., pH and DO) both locally and in downstream waters.

Notes: Criteria are applicable during the period of algae growth through senescence unless more restrictive total maximum daily load (TMDL) targets have been established to ensure the attainment and maintenance of downstream waters. DO = dissolved oxygen, ER = ecosystem respiration, GPP = gross primary production, TN = total nitrogen in mg/L, and TP = total phosphorus in mg/L.

a. Seasonal average of ≥ 4 samples collected during the period of algae growth through senescence will not be exceeded. Sites will be assessed using the higher of TN and TP threshold classifications.

b. Response data, when available, will be used to assess aquatic life use support or as evidence for additional site-specific investigations to confirm impairment or derive and promulgate a site-specific exception to these criteria.

c. Daily whole stream metabolism obtained using open-channel methods. Daily values are not to be exceeded on any collection event.

d. Filamentous algae cover means patches of filamentous algae > 1 cm in length or mats > 1 mm thick. Not to be exceeded daily stream average, based on at least 3 transects perpendicular to stream flow and spatially dispersed along a reach of at least 50 meters.

e. Quantitative estimates are based on reach-scale averages with at least three measures from different habitat units (i.e., riffle, run) made with quantitative visual estimation methods.

f. Excluded waters identified in UAC R317-2-14, Footnotes for Table 2.14.7 and Table 2.14.8.

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Benchmarking with Other Investigations

How do the proposed numeric nutrient criteria compare with other water quality benchmarks?

Statistically significant thresholds are not always ecologically significant. Evaluating multiple lines of evidence is one way to increase confidence that statistical thresholds are ecologically meaningful in the context of setting NNC that are protective of biological integrity in headwater streams. In this respect, the fact that the thresholds for several independently measured responses are similar is encouraging. In addition, several thresholds were compared with other existing and independently developed water quality benchmarks. For instance, metabolism metrics, especially respiration (Figure 8), correspond with both higher nutrient concentrations and the proportion of instantaneous DO observations that are potentially stressful to stream biota. A similar pattern was observed for organic matter standing stocks (Ostermiller et al. 2018, Chapter 6)). Similarly, the structural indicators revealed a close correspondence between O/E scores—a metric that DWQ uses to assess stream condition—and nutrient thresholds (Ostermiller et al. 2018, Chapter 7). The correspondence with the proposed NNC and these independent measures of condition provides additional support that the proposed NNC are appropriate and ecologically meaningful.

How do the proposed numeric nutrient criteria compare with those proposed by others?

The proposed nutrient criteria overlap with TMDL endpoints established for Utah and NNC proposed for other mountain ecoregions. Montana DEQ recently proposed seasonal NNC for TN at 0.250–0.325 mg/L and—with one exception of an isolated volcanic range—proposed NNC for TP ranging from 0.025–0.030 mg/L (Suplee and Watson 2013). NNC proposals from other western states are also similar. In Colorado, stream nutrient criteria of 0.090 mg/L TP and 0.84 mg/L TN were recommended to protect cold water fish, although these have not yet been approved by USEPA. Other western states, like Arizona and California currently only have TN or TP criteria for a limited number of streams, with values that are commensurate with those proposed by DWQ. Outside of Utah, but within the western US, several studies have used different distribution approaches to propose NNC and values for streams within USEPA Aggregate Nutrient Ecoregion II (western Forested Mountains) range from 0.08–0.21 mg/L for TN and 0.003–0.020 mg/L for TP (see Evans-White et al. 2014 for summary).

How do the proposed numeric nutrient criteria compare with thresholds identified in the scientific literature?

The proposed NNC are also consistent with protective concentrations of N or P that other scientific investigations have concluded were indicative of healthy stream conditions (Figure 7, black symbols). Biggs (2000) recommended that dissolved inorganic N and SRP remain below 0.019 and 0.002 respectively to avoid nuisance algae growth (200 mg/m^2 chl-*a* for a 50-day accrual). *Cladophora*, a filamentous alga that sometimes leads to nuisance algae growth in Utah streams, has a higher likelihood of reaching nuisance levels when TN exceeds 0.6–1 mg/L or TP exceeds 0.02–0.04 mg/L or (Dodds 1992, Stevenson et al. 2006), although the extent to which nuisance levels are attained depends on the frequency and magnitude of flooding events (Freeman 1986). Dodds and colleagues (2006) evaluated regional nutrient-algae relationships and derived criteria of 0.4–0.6 mg/L TN and 0.027–0.062 for TP.

Higher organisms are also known to be affected by excess nutrients, although relationships are indirect and some caution against overly depending on these responses (USEPA 2014). Wang and colleagues (2007) evaluated macroinvertebrate responses and found TP thresholds of 0.04-0.09 mg/L and TN thresholds of 0.6-1.6 mg/L, depending on the specific metric evaluated. The same authors evaluated effects on fish and found thresholds for salmonid metrics at approximately 0.6 mg/L TN and approximately 0.06 mg/L TP.

PROGRAMMATIC IMPLICATIONS

Monitoring

DWQ will maintain responsibility for monitoring and assessing if headwater stream water quality is meeting the NNC for TN and TP and evaluating ecological responses. DWQ relies on data collected by partners in addition to data collected by DWQ. DWQ anticipates incorporation of data collection efforts into ongoing cooperative monitoring agreements with appropriate partner agencies such as the USFS. DWQ has explored how to best integrate the collection of these data into existing and ongoing monitoring programs. Currently, DWQ conducts three different monitoring strategies, with each serving different DWQ program needs. This section describes how nutrients and ecological responses will be integrated into ongoing

MONITORING EFFORTS DIRECTLY RELATED TO THESE NUMERIC NUTRIENT CRITERIA

50 RANDOMLY SELECTED SITES, TWO-YEAR ROTATION

Water Chemistry Sample

Sites will be prioritized for additional data collection if either TN or TP exceeds the lower threshold.

Benthic Algae Cover

Samples are collected that will allow assessment of recreation use criteria.

INTENSIVE WATER CHEMISTRY COLLECTIONS AT PRIORITY SITES

Water Chemistry Samples

Four or more samples will be collected during summertime months for calculation of seasonal averages.

Filamentous Algae Cover

Quantitative visual assessments will be made monthly during water chemistry collections.

Metabolism

Sondes will be deployed for 3–5 weeks, which will permit as many as 35 measures of daily GPP and ER.

monitoring efforts.

The first type of monitoring uses a spatially balanced, stratified, random sampling design called generalized random tessellation stratified. Each year, 25 sites are selected statewide for tier 1 sampling. At each of these sites, approximately one day is spent monitoring multiple chemical, physical, and biological water quality indicators during the summertime growing season (Table 5). This includes collection of water chemistry data for dissolved TP and TN and individual N analytes including: Kjeldahl N, nitrate-nitrite and ammonium. In addition, these collection efforts currently include collection of a reach-scale benthic algal sample for chl-*a* and ash free dry mass (AFDM) analysis. DWQ is refining field and laboratory methods to better quantify algae cover in circumstances with high filamentous algae cover. These new methods will allow DWQ to assess each of these sites against the proposed recreation criteria. Sites where the TP or TN data exceed the lower summertime average criteria will be prioritized for subsequent intensive monitoring efforts.

While assessments derived from randomly selected sites are comprehensive with respect to the breadth of data collection, their disadvantage is that there is generally a single water chemistry sample collected at these locations. Because of this limitation, DWQ established a more sample intensive water chemistry data monitoring approach in which sites are sampled at least once per month over a water year, which is a sufficient collection frequency to routinely meet the minimum sample size requirements specified in the NNC. Intensive monitoring sites also rotate among the six major management basins with sampling conducted two years after probablistic assessments are completed. Sites are selected for inclusion in intensive monitoring efforts based, in part, on probablistic results; sites where the probabilistic sample exceeds the lower threshold of TN or TP will be prioritized for intensive monitoring. At each of these sites, sondes will be deployed for 3–5 weeks for the purpose of obtaining whole stream metabolism (GPP and ER) data (Table 6). DWQ also proposes adding quantitative visual filamentous algae cover measurements, which will be collected at least monthly during water chemistry collection events (Stephenson and Bahls 1999, Stevenson et al. 2006).

Table 5. Current and Proposed Water Quality Indicators Collected in Conjunction with Probablistic Monitoring Efforts

Indicator	Intensity	Frequency
Existing		
Macroinvertebrates Assemblage Condition (O/E)	1 spatially integrated sample	Once in growing season
Fish Assemblage Condition Multi-Metric Index	1 spatially integrated sample	Once in growing season
Benthic Algae Cover	1 spatially integrated sample[a]	Once in growing season
Algae Assemblage Condition	1 spatially integrated diatom sample; assessment methods are in development	Once in growing season
Water Column Nutrients	1 grab sample	Once in growing season
Habitat Health	Multiple parameters are currently measured	Once in growing season
pH and DO (Nutrient-related Core Water Quality Indicators)	1 instantaneous measurement	Once in growing season
Discharge	1 instantaneous measurement	Once in growing season
Measures to be Added in Support of these Proposed Criteria		
Benthic Algae Cover[a]	1 Day	Once in growing season
High Frequency pH and DO	3–7 days	Independently assessed, once in growing season

Note: Probabilistic monitoring is conducted at 25 randomly selected streams yearly. Existing indicators are those that are currently monitored and assessed. Measures to be added are those that will be incorporated into this tier in conjunction with implementation of the nutrient reduction program. Other related indicators are in development, which means that they are currently monitored, but assessment methods are in development.

[a] Refine current collection methods to better quantify filamentous algae; data will be used to assess recreation uses.

Table 6. Current and Proposed Water Quality Indicators Collected in Conjunction with Intensive Monitoring Efforts

Indicator	Intensity	Frequency
Existing		
Water Column Nutrients	1 grab sample	≥ Monthly
pH and DO (Nutrient-related Core Water Quality Indicators)	1 instantaneous measurement	≥ Monthly
Measures to be Added in Support of these Proposed Criteria		
Percent Filamentous Algae	1 reach-scale estimate	≥ Monthly
Metabolism Data (GPP, ER)	3–5 weeks	At priority sites[a]
Benthic algal biomass (Chl-a and AFDM)	1 reach-scale estimate	At priority sites[a]

Note: Intensive monitoring water quality indicators are collected 1–2 times per month in each watershed management unit two years after probabilistic sample data were collected. For the nutrient reduction program, these sites will be selected based on information obtained in previous collection events (see also Figure 10).

[a]Sites where nutrients exceed lower TN and TP threshold, violate O/E assessments, or indicate excessive algae growth.

Finally, additional monitoring is conducted as needed to inform specific programmatic needs that are not met by data collected in the first two sampling designs (Table 7). For Utah's nutrient reduction program, this approach will be used to collect the data necessary for site-specific standard development or for further validation of assessment conclusions.

Table 7. Current and Proposed Water Quality Indicators Collected in Conjunction with Programmatic Monitoring Efforts

Investigations	Intensity	Frequency
Existing		
Wasteload Allocation Synoptic/ Qual2K models	2–3 days downstream of major facilities	Once/3 years
TMDL Investigations	Varies depending on the age and complexity of the report	Most recent report is used (if available)
Measures to be Added in Support of these Proposed Criteria		
Supplemental Ecological Responses	As needed	As needed

Note: Ongoing and proposed programmatic monitoring efforts consist of intensive investigations aimed at informing specific water quality programs. For the nutrient reduction program, existing data and information would be augmented with supplemental empirical responses to develop site-specific standards. In the case of headwaters, these investigations would be conducted if there is evidence that regional criteria are either overprotective or underprotective of existing uses.

Assessment

The breadth of nutrient indicators that DWQ developed and evaluated to generate the proposed NNC provide an opportunity to refine nutrient-related water quality assessments to be more accurate than has historically been possible. A draft assessment process for headwater streams is presented below. DWQ will continue to collaborate with stakeholders to refine these approaches to better identify and prioritize sites with potential nutrient-related problems. DWQ aligned the assessment methods as closely as possible to USEPA guidance on conformational criteria; however the three levels established by these proposed criteria makes these specific circumstances unique. Modifications to these rules may be needed in the final version of this proposal.

Decision Rules

The assessment methods for the proposed combined criteria are shown in Table 8. Additional assessment details, where appropriate, will be developed and submitted for public comment biennially as part of Utah's *Integrated Report* methods. With these proposed NNC, there are two ways that a site would be considered to be supporting aquatic life uses with respect to nutrients. First, a headwater stream would be considered to be meeting its aquatic life uses if the lower (and by default the upper) NNC for average summertime TN and TP criteria, and responses are either unavailable or no measured response exceed specified thresholds. Sites where TN or TP fall within the middle, or moderate enrichment level would also be considered to be meeting their aquatic life uses provided that at least one response has been measured and no response that has been measured exceeds the established thresholds. In contrast, sites that fall within the middle, moderate enrichment level, would be considered to be impaired if <u>any</u> response that has been measured exceeds the thresholds established with the NNC. In circumstances where a response is required to make an assessment decision, it is not necessary to have data on all responses specified in the NNC. An individual response should be sufficient to make a conclusion based on existing and readily available data and information. If other indicators are collected in the future that contradict an assessment decision, options for changing the listing will be explored in the next biennial assessment cycle or through other remediation activities.

Table 8. Decision Matrix That Will Be Used to Assess Support of Headwater Aquatic Life Uses for Nutrient-related Water Quality Problems

		Ecological Responses		
		No Data	< All Criteria	> Any Criterion
Nutrient Data (TN or TP)	No Data or < 4 Samples	Not Assessed[a]	Not Assessed[a]	Impaired (5)[b]
	< Low Threshold	Not Assessed[a]	Fully Supporting (1 or 2)[d,f]	Impaired (5)[b,e]
	Between Lower and Upper Threshold	Insufficient Data (3A)[c]	Fully Supporting (1 or 2)[d]	Impaired (5)
	Above Upper Threshold	Threatened (5)[f,]	Threatened (5)[e,f,]	Impaired (5)

Note: Associated *Integrated Report* categories are in parentheses.
[a]There are insufficient <u>nutrient-related</u> data to assess whether or not aquatic life uses are supported; however, aquatic life uses may be assessed with other water quality parameters.
[b]Sites where an ecological response threshold has been exceeded, but the lower TN and TP thresholds have not will be listed as impaired on the <u>basis of a biological assessment</u>; cause will be listed as unknown pending follow-up investigations.
[c]Sites where TN or TP fall below the upper threshold, but above the lower threshold, and lack measures for at least one response variable will not be assessed with respect to nutrients. These sites will be <u>prioritized for follow-up monitoring.</u>
[d]The integrated report distinguishes between sites where at least one parameter has been evaluated for <u>all</u> uses (Category 1) and sites where some uses are supported, and other uses are either not supported or not assessed (Category 2).
[e]Sites where nutrient and ecological response data are in conflict may be <u>candidates for site-specific criteria</u>.
[f]Sites below both the lower TN and TP thresholds with at least one response below the lower threshold will be considered to be fully supporting aquatic life uses unless another nutrient-related criterion (e.g., pH, DO) suggests otherwise..

Any headwater stream with a summertime average TN or TP concentration above the upper threshold with either non-existent or contrasting ecological confirmation data would be considered to be exceeding the NNC. The stream would be classified as threatened until DWQ can more thoroughly evaluate local and downstream degradation of designated uses. If these investigations demonstrate undegraded conditions at a high enrichment stream including downstream reaches, site-specific standards will be developed and promulgated as an exception to these proposed rules.

Assessment decisions in circumstances where nutrients and response data conflict, or where summertime nutrient averages or response data are unavailable, are not as straightforward. For instance, there may be circumstances where fewer than four samples are available for both TN and TP, in which case data quality objectives are not met and summertime average nutrient calculations are invalid. These sites will not be assessed until additional summertime samples can be collected. The collected samples can still be used to prioritize sites for additional monitoring in subsequent monitoring rotations. It is also important to consider circumstances where TN and TP data conflict with one another. If either TN or TP is above an NNC threshold then the site would be considered in the higher enrichment group and evaluated accordingly. However, a demonstration that either TN or TP falls below the lower threshold is sufficient to make a decision of full support with respect to nutrient enrichment, provided that existing response data are not reflective of a threat to aquatic life uses.

It is also possible, albeit atypical, that a site may fall below the lower threshold for both TN and TP but exceed the criteria thresholds for an ecological response. For instance, water column nutrients could potentially be diminished due to high nutrient uptake rates in highly productive waters. Should such a circumstance arise, interpretation of the data the data for purposes of making impairment determination presents a conundrum. On one hand, manifestations of responses generally considered to be problematic are reflective of a potential threat to aquatic life. On the other hand, there is no evidence that nutrient enrichment is the cause of these responses. As a result, DWQ proposes listing such sites as impaired on the basis of a biological assessment with unknown cause. Follow-up investigations will then be conducted to identify the causes of these impairments, including whether or not human-caused N or P inputs are contributing stressors. In circumstances where observed responses are determined to be naturally-occurring, site-specific NNC criteria will be established for the site.

Any threatened impairment determination falls into the same *Integrated Report* category (5) as impairment designations, but differ from impairments with respect to the DWQ process followed when seeking solutions. One a stream is designated as threatened, DWQ will conduct additional investigations to better understand the nature and extent of the impairment before instigation of a formal TMDL process. If these follow-up investigations demonstrate that the observed response are due to natural conditions or irreversible hydrologic modification, then such a site-specific standard would be proposed and ultimately promulgated as site-specific criteria. Otherwise, a TMDL would be instigated with a more thorough understanding of any human-caused conditions contributing to the excursions of response thresholds.

Identifying Causes and Sources for the Integrated Report

DWQ will use a weight of evidence approach to determine whether nutrients (either TN or TP) contribute to any observed impairments. However, in some circumstances it is possible that deleterious responses are also caused by other stream stressors. For instance, degraded riparian conditions may contribute to excessive GPP. Similarly, steam channel modification could potentially contribute to excessive ER by trapping sources of carbon that would otherwise be transported downstream. If the weight of evidence suggests that other causes are contributing to an impairment the cause may be listed with a more general “eutrophic conditions” so that subsequent investigations can establish the relative importance of different stressors and/or the relative extent to which TN or TP is contributing to the impairment. Programmatically, this distinction may be important because it could potentially allow DWQ to focus remediation efforts on restoring ecological responses instead of setting goals that are exclusively based on nutrient reductions (see the section "Addressing Nutrient-Related Impairments: TMDL Alternatives" below). Such investigations are critically important because they can inform the specific remediation practices that are most likely to improve stream conditions and restore support of uses.

DWQ will list the source of nutrients as unknown, even in circumstances where DWQ staff conclude that TN or TP causes or contributes to an impairment. An early step in the TMDL—or alternative remediation planning—process will be quantification of both natural and human-caused sources of TN or TP. Once sources have been accurately quantified, DWQ will subsequently modify the impairment listing to reflect known sources in the next *Integrated Report* cycle. In circumstances with domestic livestock grazing identified as an important contributing factor, DWQ will work collaboratively with UDAF, USFS, and any affected permit holders to identify effective and equitable solutions. Sites with high background conditions may be candidates for site-specific modifications to the proposed NNC.

Preliminary Assessment Results

Evaluation of Historical Data

Response data were not historically available. In order to investigate the potential ramifications of these proposed headwater criteria, DWQ gathered all TN and TP data for the most recent nine years of available records. Due to a paucity of organic N data in historic records TN was predicted from TIN ($r^2 = 0.92$, $p < 0.001$). Summertime averages were then calculated for all samples collected during the period of algae growth through senescence. Not surprisingly, N and P concentrations at sites within headwater streams were low in comparison with statewide estimates (Table 9).

Table 9. Comparisons, Expressed as Percentiles, of Headwaters and Statewide Growing Season Average Ambient Nutrient-concentration Data

	Percentiles			
	25th	50th	75th	90th
Total Nitrogen (mg/L)				
Headwaters	0.10	0.24	0.38	0.56
All Sites	0.18	0.25	0.50	1.1
Total Phosphorus (mg/L)				
Headwaters	BRL	0.019	0.038	0.058
All Sites	BRL	0.04	0.05	0.15

Notes: Headwater distributions for TP (n = 494 sites) and TN (n = 448 sites) are among-site comparisons of summertime average nutrient concentrations derived from all samples collected from 2002–2012. Statewide (all sites) percentile estimates were obtained from cumulative distribution functions derived from samples collected at 50 randomly selected perennial streams. BRL stands for below laboratory reporting limits.

Based on this review of the summertime average nutrient concentrations collected over the most recent nine years of available data, DWQ concludes that most headwater streams are generally in good condition with respect to nutrients. For both TN and TP approximately 70% of headwater streams evaluated would be considered fully supporting their uses because the lower nutrient threshold was not exceeded. In contrast, approximately 6% of sites are threatened for TN (predTN, Figure 10) and approximately 9% of sites are threatened for TP (Figure 11) because the summertime averages exceed the upper threshold. This conclusion is not definitive for all of these sites because 1/3 of potentially impaired TP sites, or ½ of TN sites, had fewer than 4 samples. For TN and TP, about 20% of sites exceeded the lower criterion but not the upper criterion; although about 30% of these sites had fewer than four samples which may limit the general applicability of this enrichment estimate. As specified in the NNC, Ecological response data would be required to conclude degradation of these moderately enriched sites, while such data were unavailable when conducting this analysis, the results of the confirmation investigation (see below) suggest that biological uses would be maintained in about 60% of these streams.

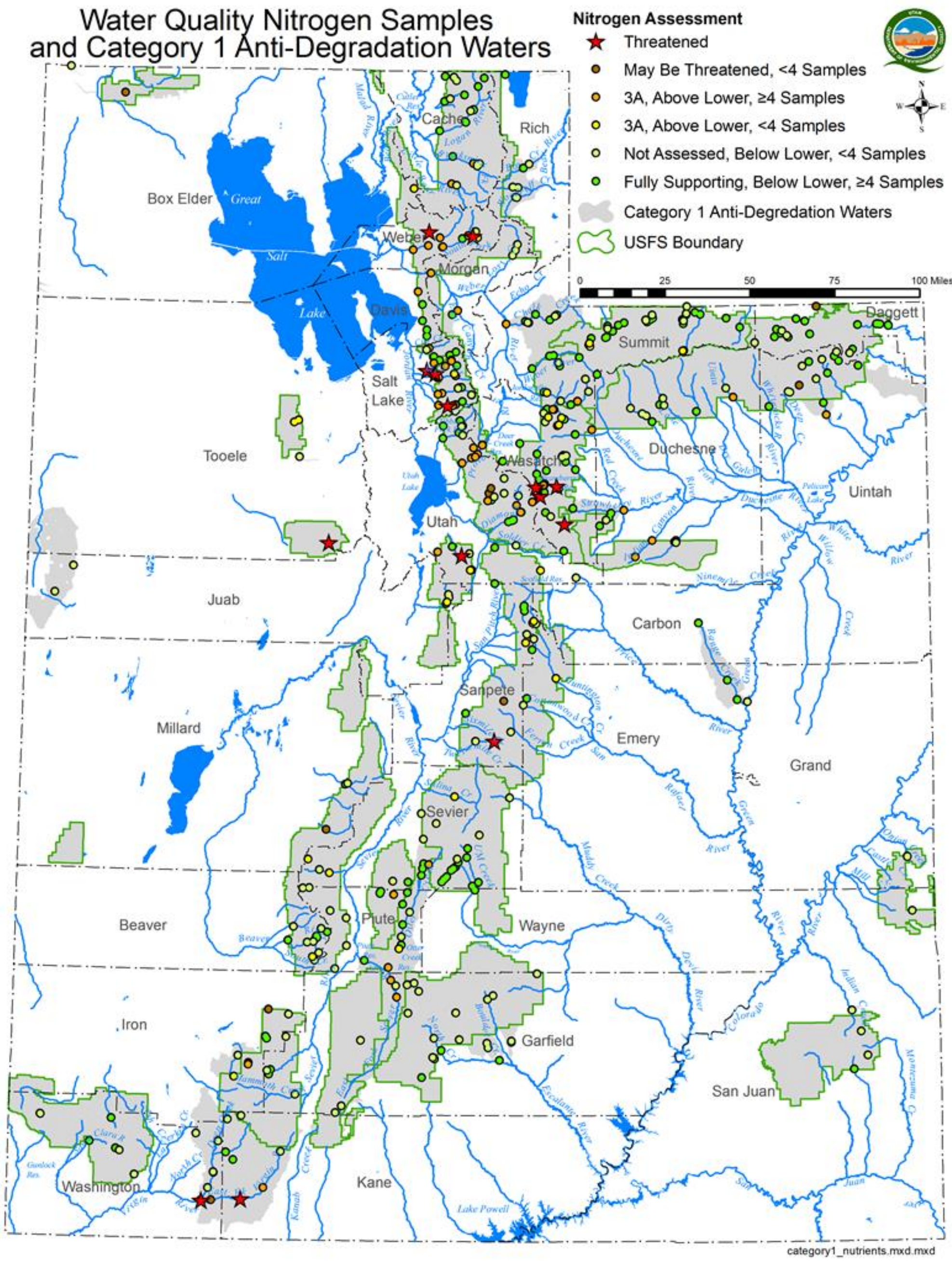

Figure 10. Preliminary assessment results for predTN at headwater streams based on summertime averages calculated from all samples that were collected over the most recent 10 years of available data.

Note: Follow-up were conducted at threatened sites to confirm the threatened status. Streams that are identified as “may be a problem” fall between the upper and lower thresholds, but do not yet have response data. Follow-up monitoring will be conducted at as many of these sites as possible, but if necessary streams where the summertime average was based on ≥ 4 samples will be prioritized. Sites below the lower threshold are not considered to be fully supporting unless ≥ 4 samples were used to calculate summertime averages.

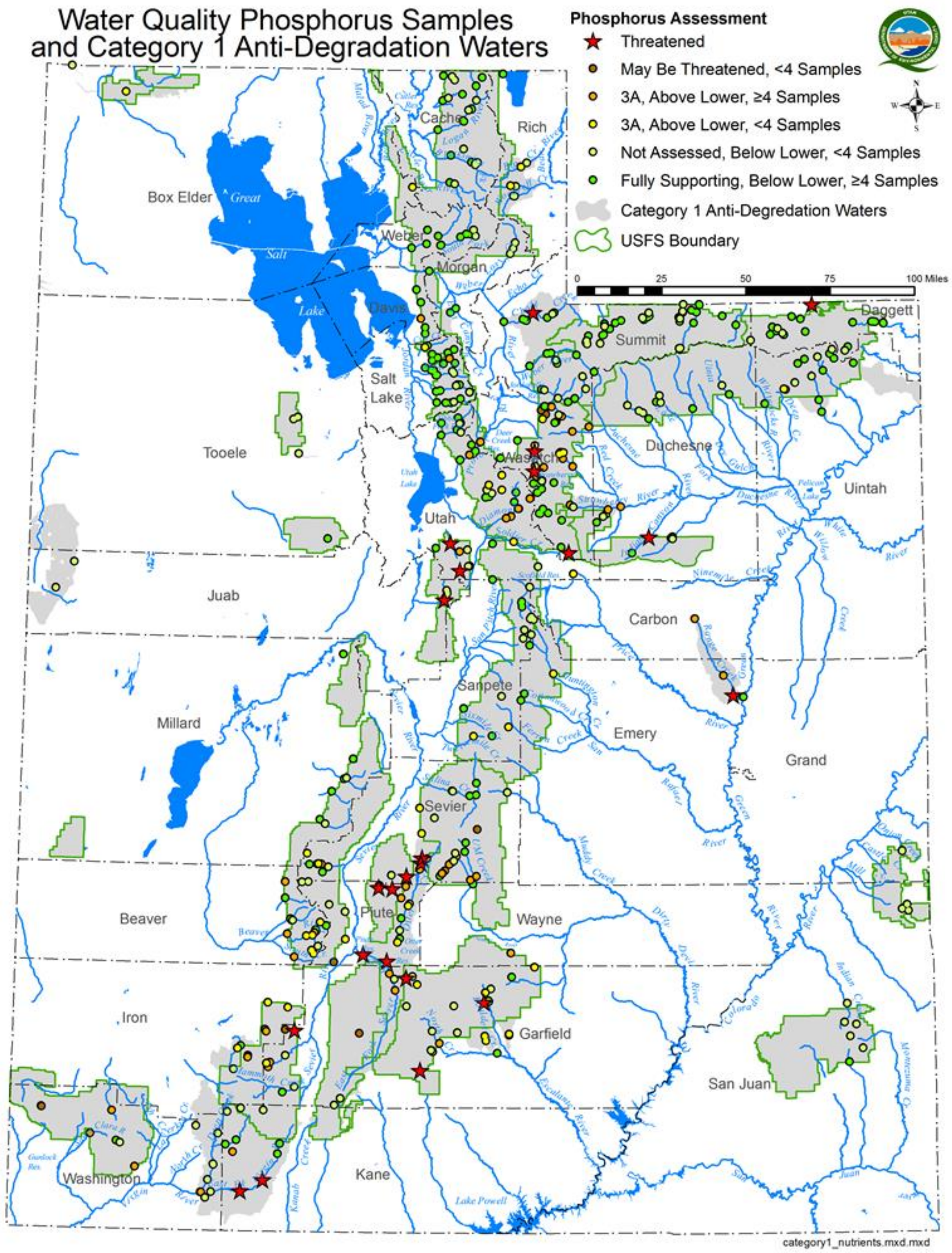

Figure 11. Preliminary assessment results for TP at headwater streams based on summertime averages calculated from all samples that were collected over the most recent 10 years of available data.

Note: Follow-up collections will be conducted at threatened sites to confirm the threatened status. Streams that are identified as "may be a problem" fall between the upper and lower thresholds, but do not yet have response data. Follow-up monitoring will be conducted at as many of these sites as possible, but if necessary streams where the summertime average was based on ≥ 4 samples will be prioritized. Sites below the lower threshold are not considered to be fully supporting unless ≥ 4 samples were used to calculate summertime averages.

Confirmation Investigation

To further evaluate the proposed headwater criteria, DWQ collaborated with UDAF and USFS to collect additional nutrient and response data from June through September in 2015. Historical data were used to identify candidate study sites based on TN or TP with priority given to those sites that exceeded proposed thresholds for TN or TP. This effort resulted in 49 sites with ambient nutrient concentrations and one or more of the proposed NNC ecological responses that could be used to further evaluate the proposed headwater NNC.

Despite targeting headwater streams with the highest nutrient concentrations, Data from this investigation suggest that Utah's headwater streams are not extensively enriched. Among all sites, growing-season average TP was 0.05 ± 0.063 mg-P/L and 0.34 ± 0.20 mg-N/L for TN. Despite these relatively low levels of enrichment, most of the study locations were reflective of human-caused nutrient enrichment. Growing-season average nutrient concentrations exceeded the upper threshold for TN at approximately 4% (2 of 49 sites) of study locations and at 14% of sites (6 sites) for TP. No study location exceeded the upper threshold for both TP and TN. Almost 60% of all study locations exceeded the lower threshold for TP, TN, or both. An additional 10 sites exceeded the proposed lower threshold for TN, and 17 sites exceeded the proposed lower threshold for TP. As specified by the proposed NNC, these more moderately enriched sites would require co-located ecological responses to determine impairment.

Examination of the ecological response data demonstrates the benefit of combining nutrient concentrations with ecological responses for making impairment determinations. There were no indications of ecological degradation at almost 60% of study locations where ambient nutrient concentrations fell between upper and lower thresholds for TN or TP. No site exceeded the threshold for GPP (> 6 g O_2/m^2/day), one site exceeded the threshold for ER (> 5 g O_2/m^2/day), and two additional sites were close to the ER threshold. With respect to filamentous algae, aerial cover exceeded 1/3 of the stream bed at eight study locations. Importantly, only one site exceeded the proposed metabolism or filamentous algae cover thresholds and did not also have TN or TP below the lower nutrient thresholds. This implies that the lower thresholds are sufficiently sensitive for use as triggers for additional information, which means that the proposed NNC would be unlikely to miss deleterious effects of human-caused enrichment on aquatic life uses.

NEXT STEPS

Future Modifications to Regional Headwater Criteria

A critical step in adaptive management is revisiting previous decisions as additional data become available. DWQ has developed the proposed NNC to be generally applicable to headwaters statewide, but there will likely be circumstances where they need to be modified. One advantage of these NNC and associated monitoring and assessment procedures is that DWQ will be expanding monitoring to include data collection for several ecological responses that are directly related to nutrient enrichment. These data may reveal the need for additional subclasses of headwater streams and the need to develop alternate nutrient or ecological response NNC specific to those subclasses. As such needs become manifest, DWQ will compile the evidence into a categorical Use Attainability Analysis, which will allow appropriate adjustments to these proposed criteria.

Another possibility is that local conditions will reveal the need to modify these regional NNC on a site-specific basis. For instance, there may be circumstances where either benthic algae or respiration numeric response indicators are exceeded, yet average N or P criteria are not. If confirmed, these observations would suggest that either N or P criteria were underprotective. The converse—that regional NNC are overprotective—is also possible. If either TN or TP exceeds the numeric criterion, yet all responses are met and no other evidence exists that existing uses are degraded, and then DWQ may modify the regional criteria on a site-specific basis using background nutrient concentrations to set criteria.

The regional NNC may also need to be modified to protect downstream uses. Both Clean Water Act regulations (40 CFR 131.10(g)) and Utah's Water Quality Standards (UAR R317-2-7.1) permit site-specific modification of regional NNC to less protective values provided that it can be demonstrated that existing aquatic life uses will remain protected or that existing criteria cannot be met due to irreversible alterations of hydrology or habitat. In the case of headwaters, DWQ anticipates that the latter circumstance would be particularly rare, with the likely exception of reservoir outlets.

Ongoing Collaborative Management

Most of the headwater streams are contained within watersheds that are managed by the USFS. Hence, NNC implementation will require ongoing collaborative management with this and other federal and state agencies. DWQ already maintains Memoranda of Understanding (MOUs) with many management agencies in Utah. These MOUs outline, among other things, collaborative monitoring practices. For example, DWQ has agreed to modify an MOU with UDAF to clearly articulate a commitment to quickly identify whether domestic livestock grazing is responsible for any impairments identified by the NNC, and if so, to work collaboratively with the USFS and potentially affected permittees to identify a suite of potential solutions that could be implemented as equitably as possible. As these proposed NNC are implemented, it will be

> **A NEW LONG-TERM VISION FOR ASSESSMENT, RESTORATION, AND PROTECTION OF WATERS**
>
> **Primary Objectives**
>
> Progress Over Pace.
>
> Focus restoration efforts where they are most likely to succeed.
>
> Consider diverse approaches for setting water quality goals
>
> Prioritize efforts to protect and restore what is most important.

critical to bolster these collaborative efforts to ensure that both nutrients and responses are measured at streams with potential nutrient-related problems. It will also be important to coordinate on analysis and interpretation of these data to assess any streams that exceed the NNC for readily apparent activities with the potential to contribute to nutrient enrichment.

Addressing Nutrient Impairments

Another important collaborative effort will be working together to determine how best to address nutrient impairments. Traditionally, DWQ has addressed water quality impairments by creating TMDLs that mandate load reductions for all pollutant sources, and TMDLs remain one option for addressing nutrient-related impairments in headwater streams. Recently, USEPA and, subsequently, DWQ have been undergoing a visioning exercise to rethink restoration practices (USEPA 2003, 2011b, 2013). Among other things, this new long-term vision calls for flexibility in the development of alternatives to TMDLs. Several proposed alternatives focus on the development and implementation of restoration efforts instead of on stricter TMDL load allocation.

USEPA's new restoration vision interfaces well with these proposed NNC and is another opportunity to expand ongoing collaborative management efforts. One such opportunity relates to the fact that the primary nutrient-related stressors in Utah's forested streams are livestock grazing, road construction and other development, catastrophic wildfires, and mining (Kershner at al. 2004). These activities are not generally thought to cause degradation if BMPs are fully implemented. These NNC can help water quality managers better prioritize where additional BMPs may be needed by more clearly defining water quality goals. For example, DWQ has already examined summertime average nutrient concentrations for headwater streams from historic (9-year) data, and the vast majority of streams appear to be in good condition. These proposed NNC allow those streams with higher nutrient concentrations to be prioritized for additional monitoring of both nutrients and responses. In some cases, sources of nutrients may be difficult to quantify because they are diffuse, whereas human activities that are responsible for increased nutrient loads may be easier to identify. Such circumstances are ideal candidates for alternative restoration plans. Successful implementation of these plans will also require collaborative management between DWQ and other management agencies to ensure that progress continues to be made toward meeting water quality goals. Finally, the incorporation of ecological responses into these NNC offers some flexibility with the specific BMPs that can be incorporated into remediation plans because water quality goals can be expressed as desirable ecological outcomes. One example would be circumstances where excess GPP could potentially be lowered by restoring riparian ecosystems, which would also likely improve the habitat of the aquatic life that these proposed criteria aim to protect.

As the above examples highlight, once a headwater is listed as impaired, DWQ and collaborators will need to begin the process of assessing the impairment in more detail to determine the most appropriate path for resolving the impairment (Figure 12). One important consideration in determining the most appropriate path to take with these investigations is the cause(s) of the impairment. If the cause is clearly related to current forest management practices (e.g., grazing, logging, recreation) then DWQ will work with USFS to update the appropriate plans for the impaired watershed. In some cases, the plans may not need to be updated but implementation and/or enforcement activities may be required to ensure that the plan is followed. If an impairment occurs in a watershed with grazing allotments, DWQ is committed to working with UDAF to quickly determine whether or not domestic livestock grazing is a causal factor. If livestock grazing is among the important causes, it will be necessary for DWQ and UDAF to expand collaborative activites to include USFS and grazing permittees to identify a suite of BMPs that could be implemented to address the problem.

If DWQ determines that the cause of the impairment is natural, then DWQ will work to develop site-specific standards for the waterbody. If the cause is not pollutant driven (e.g., it relates to habitat modification or hydrologic alteration), then the site will be reclassified to Category 4c during the next assessment cycle. Because Utah is using a bioconfirmation approach to standards and assessment, this scenario is unlikely. If the causes appear to be complex or unknown, DWQ will engage in additional studies to better understand the impairment. This could result in the development of a TMDL or identification of one of the other paths described above. The USFS will account for the impairment in all decisions under the National Environmental Policy Act until the waterbody is removed from DWQ’s list of impaired waters (Category 5).

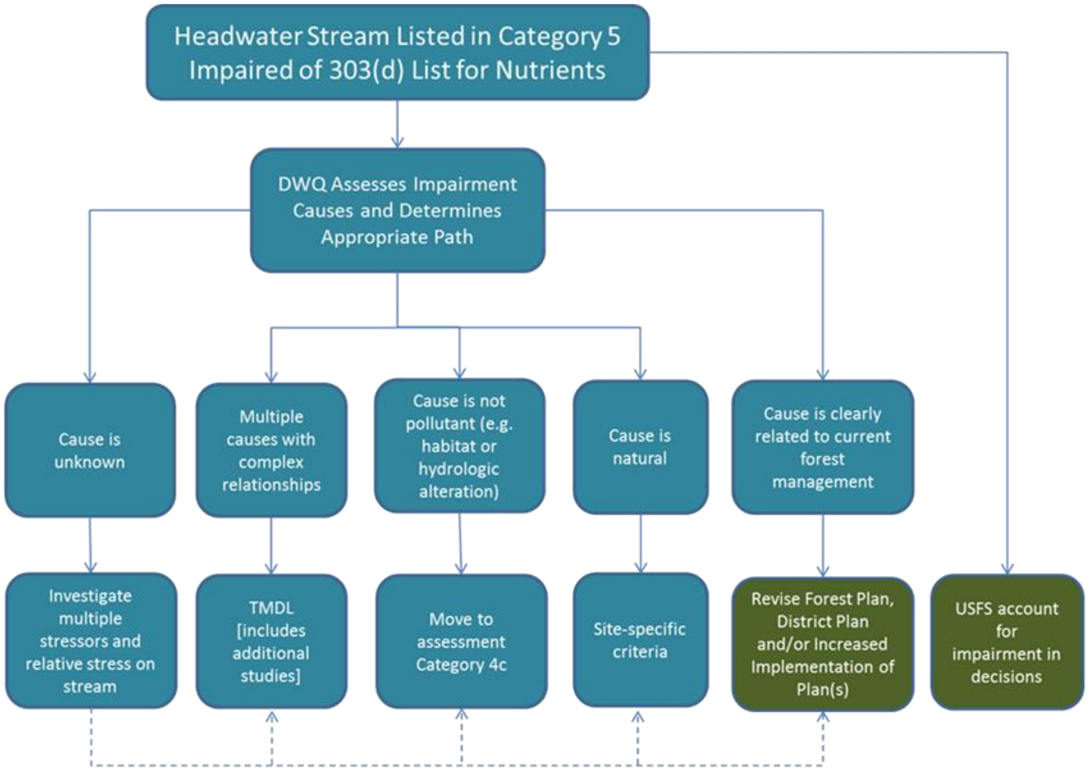

Figure 12. Summary of pathways that DWQ will follow after a headwater stream is listed as impaired for nutrients.

Conducting Site-Specific Standard Investigations

Whether DWQ or others conduct site-specific investigations, a sample and analysis plan (SAP) must be developed and approved by DWQ prior to data collection. This plan will clearly discuss the type of data to be collected, frequency of data collection, roles and responsibilities (if a collaborative process is proposed), data storage, and plans for data analysis. Development of this plan is the best way to ensure that the data can be used as efficiently and effectively as possible to support standard revisions. In addition, the plan can be shared with USEPA to ensure that once the proposed numeric criteria are submitted, they will be approved.

Generally, a minimum of 3 years of data will be required to generate sufficient information on year-to-year variation. In addition to the nutrients and responses that were used to create the headwater NNC, it may be necessary to collect other pieces of information to better understand the role of covariates in mitigating or exacerbating nutrient concentrations or ecological responses. While the specific nature of each investigation is likely to be somewhat different, DWQ envisions that these investigations will generally consist of a combination of process-based models and empirical ecological responses. The data necessary for each site and plans for data analysis shall be clearly outlined in the SAP. Admittedly, such investigations can sometimes be resource intensive. DWQ will continue to evaluate the need for site-specific modifications to the proposed headwater NNC on an ongoing basis.

Consideration of Site-Specific Data

DWQ will consider the following when evaluating site-specific investigations:

- The risk of degraded conditions under feasible future scenarios
- Natural conditions that exacerbate or diminish the effects of nutrients and the likelihood of these conditions changing
- The role of natural sources of nutrients
- The risk of increased nutrients in downstream waters

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APPENDIX: PROPOSED RULE LANGUAGE

Sections with proposed changes were excerpted from the rule language, with blue text and line ---Breaks---, and smaller (within text) breaks denoted with …
Changes are in red text.
The proposed deletions are shown in bracket, [~~strikeout~~] font
The proposed additions are shown as underlined and green highlighting

R317. Environmental Quality, Water Quality.
R317-1. Definitions and General Requirements.
R317-1-1. Definitions.
Note that some definitions are repeated from statute to provide clarity to readers.

------------------------Break------------------------------------

"Ecosystem respiration (ER)"means the spatially explicit rate of organic degradation derived from open channel, diel stream oxygen models.

…

"Filamentous Algae Cover" means patches of filamentous algae greater than 1 cm in length or mats greater than 1 mm thick, expressed as the proportion of visible stream bed where it observed and where it is not.

"Gross primary production" means the spatially explicit rate of autotrophic biomass formation derived from open channel, diel stream oxygen models.

---------------------END OF R317-1 CHANGES----------------------

Sections with proposed changes were excerpted from the rule language, with blue text and line ---Breaks---, and smaller (within text) breaks denoted with …
Changes are in red text.
The proposed deletions are shown in bracket, [~~strikeout~~] font
The proposed additions are shown as underlined and green highlighting

R317. Environmental Quality, Water Quality.
R317-2. Standards of Quality for Waters of the State.

------------------------Break-----------------------------------

R317-2-10. Laboratory and Field Analyses.

10.1 Laboratory Analyses

All laboratory examinations of samples collected to determine compliance with these regulations shall be performed in accordance with standard procedures as approved by the Director by the Utah Office of State Health Laboratory, or by a laboratory certified by the Utah Department of Health.

10.2 Field Analyses

All field analyses to determine compliance with these rules shall be conducted in accordance with standard procedures specified by the Utah Division of Water Quality or with methods approved by the Director.

------------------------Break-----------------------------------

R317-2-14. Numeric Criteria.

TABLE 2.14.1
NUMERIC CRITERIA FOR DOMESTIC,
RECREATION, AND AGRICULTURAL USES

Parameter	Domestic Source 1C(1)	Recreation and Aesthetics 2A	Recreation and Aesthetics 2B	Agri-culture 4
BACTERIOLOGICAL (30-DAY GEOMETRIC MEAN) (NO.)/100 ML) (7)				
E. coli	206	126	206	
MAXIMUM (NO.)/100 ML) (7)				
E. coli	668	409	668	
PHYSICAL				
pH (RANGE)	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0

Turbidity Increase (NTU)			10	10	
METALS (DISSOLVED, MAXIMUM MG/L) (2)					
Arsenic	0.01				0.1

…

POLLUTION INDICATORS (5)			
BOD (MG/L)	5	5	5
Nitrate as N (MG/L)	4	4	
Total Phosphorus as P (MG/L)(6)	0.05	0.05	

FOOTNOTES:

(1) See also numeric criteria for water and organism in Table 2.14.6.

(2) The dissolved metals method involves filtration of the sample in the field, acidification of the sample in the field, no digestion process in the laboratory, and analysis by approved laboratory methods for the required detection levels.

…

(5) Investigations should be conducted to develop more information where these pollution indicator levels are exceeded. These indicators are superseded by numeric criteria in waters where promulgated.

-------------------------Break----------------------------------

TABLE 2.14.2

NUMERIC CRITERIA FOR AQUATIC WILDLIFE(8)

Parameter	Aquatic Wildlife 3A	3B	3C	3D	5
PHYSICAL					
Total Dissolved Gases	(1)	(1)			

…

Parameter	3A	3B	3C	3D	5
POLLUTION INDICATORS (10)					
Gross Alpha (pCi/L)	15	15	15	15	
Gross Beta (pCi/L)	50	50	50	50	

BOD (MG/L)	5	5	5	5
Nitrate as N (MG/L)	4	4	4	
Total Phosphorus as P(MG/L) (12)	0.05	0.05		

…

(12) Total Phosphorus as P (mg/l) as a pollution indicator for lakes and reservoirs shall be 0.025. Superseded by numeric criteria in waters where promulgated.

--------------------------BREAK--------------------------------

TABLE 2.14.7
NUTRIENT CRITERIA FOR CLASSES 2A and 2B (1)

Nutrient Parameters	Criteria
Periphyton	125 mg/m2 chlorophyll-a
	or
	49 g/m2 ash free dry mass

FOOTNOTES:
(1) Applicable to all Category 1 and Category 2 streams with the following exceptions: Quitchupah Creek through Convulsion Canyon from U. S. Forest Service boundary upstream to East Spring Canyon headwaters; North Fork of Quitchupah Creek from the U. S. Forest Service boundary upstream to its confluence with South Fork; Huntington Creek from U. S. Forest Service boundary to confluence with Crandall Creek and Crandall Creek to headwaters.

TABLE 2.14.8
NUTRIENT CRITERIA FOR CLASSES 3A, 3B, 3C, and 3D(1)

Nutrient Parameters	Criteria(2)
Total Phosphorus	0.035 mg/L)(3), and
Total Nitrogen	0.40 mg/L)(3),
	or
Total Phosphorus	0.080 mg/L(3), and
Total Nitrogen	0.80 mg/L(3), and
Filamentous Algae	33% cover(4), or
Gross Primary Production	6 g O2/m2-day(5), or

Ecosystem Respiration 5 g O2/m2-day(5)

FOOTNOTES:
(1)Applicable to all Category 1 and Category 2 streams with the following exceptions: Quitchupah Creek through Convulsion Canyon from U. S. Forest Service boundary upstream to East Spring Canyon headwaters; North Fork of Quitchupah Creek from the U. S. Forest
Service boundary upstream to its confluence with South Fork; Huntington Creek from U. S. Forest Service boundary to confluence with Crandall Creek and Crandall Creek to headwaters.
(2)For water quality assessments, Table 8, Decision Matrix That
Will Be Used to Assess Support of Headwater Aquatic Life Uses for Nutrient-related Water Quality Problems, "Proposed Nutrient Criteria
Utah Headwater Streams", Utah Division of Water Quality, March, 2019
is incorporated by reference.
(3)Not to be exceeded seasonal average for the index period of algal growth through senescence.
(4)Not to be exceeded average based on at least 3 transects perpendicular to stream flow and spatially dispersed along a reach of at least 50 meters
(5) Not to be exceeded during the index period of algal growth through senescence.

Table 8 from Proposed Nutrient Criteria: Utah Headwater Streams, referenced by rule.

Table 8. Decision Matrix That Will Be Used to Assess Support of Headwater Aquatic Life Uses for Nutrient-related Water Quality Problems

		Ecological Responses		
		No Data	< All Criteria	> Any Criterion
Nutrient Data (TN or TP)	No Data or < 4 Samples	Not Assessed[a]	Not Assessed[a]	Impaired (5)[b]
	< Low Threshold	Fully Supporting (1 or 2)[d]	Fully Supporting (1 or 2)[d]	Impaired (5) [b,e]
	Between Lower and Upper Threshold	Insufficient Data (3A)[c]	Fully Supporting (1 or 2)[d]	Impaired (5)
	Above Upper Threshold	Threatened (5)[f,]	Threatened (5)[e,f,]	Impaired (5)

Note: Associated *Integrated Report* categories are in parentheses.
[a]There are insufficient nutrient-related data to assess whether or not aquatic life uses are supported; however, aquatic life uses may be assessed with other water quality parameters.
[b]Sites where an ecological response threshold has been exceeded, but the lower TN and TP thresholds have not, will be listed as impaired on the basis of a biological assessment; cause will be listed as unknown pending follow-up investigations.
[c]Sites where TN or TP fall below the upper threshold, but above the lower threshold, and lack measures for at least one response variable will not be assessed with respect to nutrients. These sites will be prioritized for follow-up monitoring.
[d]The integrated report distinguishes between sites where at least one parameter has been evaluated for all uses (Category 1) and sites where some uses are supported, and other uses are either not supported or not assessed (Category 2).
[e]Sites where nutrient and ecological response data are in conflict may be candidates for site-specific criteria.
[f]Sites designated as threatened will automatically become impaired within two assessment cycles unless it can be demonstrated that biological uses are fully supported both locally and protective of downstream uses.